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ABSTRACT

Appropriate technology (the process most appropriate for local cultural, economic, and social conditions) is geared toward projects which: are small in scale, decentralized, and energy efficient; use local materials, labor, and ingenuity; are not capital-intensive; and maximize the use of renewable energy resources. Descriptions of such projects (carried out between 1979 and 1983 in Arkansas) are presented under six headings: (1) retrofits for conservation; (2) active solar energy; (3) passive solar energy; (4) wind and photovoltaics; (5) biomass; and (6) energy center. Included with the descriptions are: sources for additional information; pictures, drawings, and charts for clearer understanding; instructions to follow when building or assembling various devices; rough dollars-and-cents evaluations; and the experiences of the individuals completing the projects. It is assumed that individuals reading this book have some knowledge of basic terms, processes, and applications in alternate-energy technology. These individuals include people who wish to lower their energy bills and increase their self-reliance and people with some technical training who are interested in engineering and design aspects of these technologies, as well as economic concerns. (JN)

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Achieving Self-reliance: Backyard Energy Lessons

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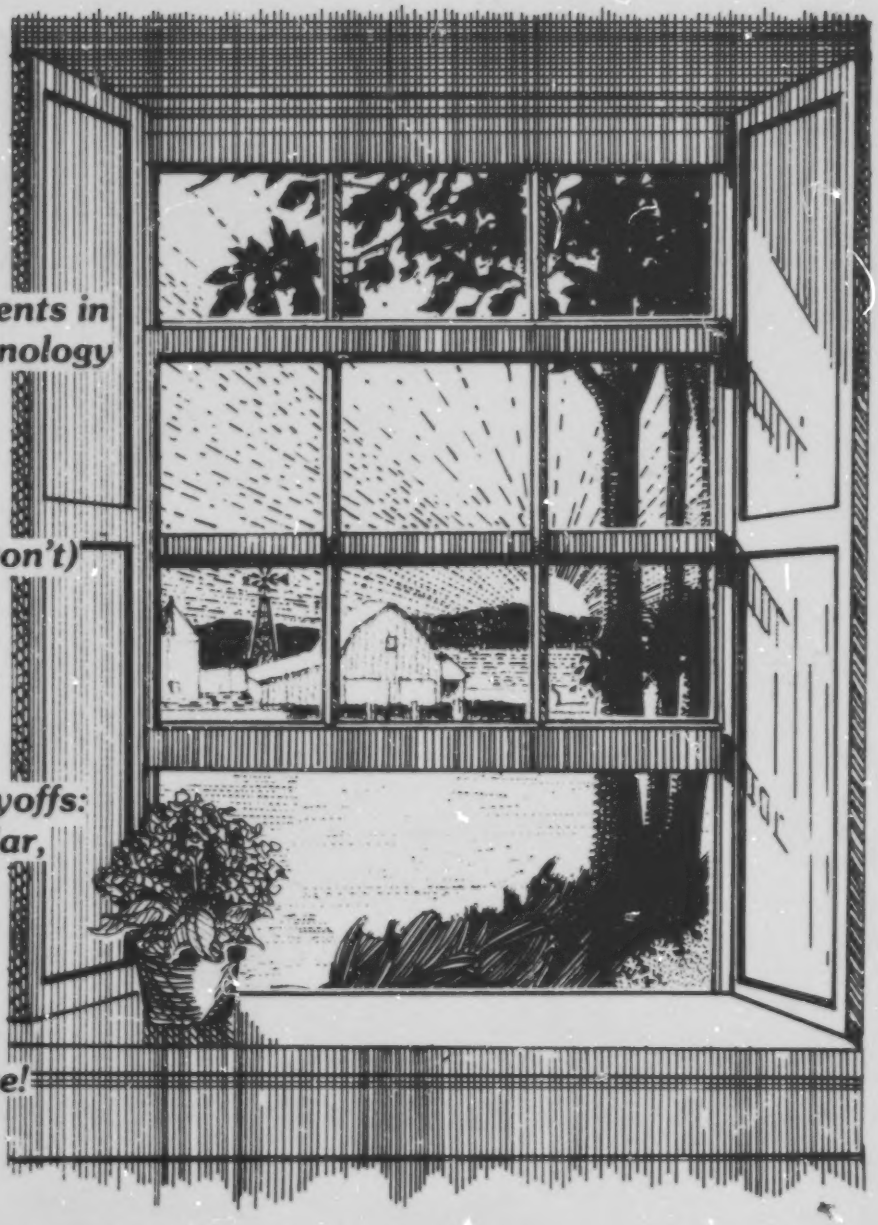

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Bill Clinton, Governor

June, 1984

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Appropriate Technology can be described as the technology or process which is, when put into practice, the most appropriate for local cultural, economic, and social conditions. It is geared toward projects which are small in scale; decentralized; energy efficient; use local materials, labor, and ingenuity; are not capital-intensive; and maximize the use of renewable energy resources.

The purpose of the Appropriate Technology Small Grant Program is to encourage individuals, small businesses, communities, and community groups both to develop energy-related ideas and to become involved in energy research and development.

These energy ideas should:

- Minimize the use of nonrenewable resources and/or technologies or processes that are not environmentally sound;
- Encourage the use of local materials and labor skills to satisfy community needs while increasing self-reliance and energy understanding;
- Use new technologies and/or novel or scaled-down applications of existing technologies to create durable, recyclable systems that are simple to install, operate, and maintain.

Excerpt from the application form for the Appropriate Technology Small Grant Program of the United States Department of Energy.

Introduction

A recent Gallup Poll has reported that solar is America's most preferred energy source, with 77% favorable to its residential use . . . However, 73% felt that they did not know enough about solar to make a decision about using it in their homes. Of these, 46% said they needed more technical information and 32% said cost and savings information were needed.

News Item, 1982

Achieving Self Reliance: Backyard Energy Lessons was written to help bridge this solar energy-education gap.

The major backyard energy lesson is that a measure of self-reliance can be achieved, in many cases, but it requires work, ingenuity and persistence. Careful study and planning to adapt suitable technologies to specific sites and situations help ensure a sound investment of one's time, energy and money. These backyard energy lessons can guide both do-it-yourself enthusiasts and consumers of commercially-made products.

This is not an introductory volume. It is assumed readers have some knowledge of basic terms, processes and applications in alternate-energy technology. If this is not the case, readers may consult the companion volume: *Free! New and Improved Energy for Arkansas* or other references in the annotated listing at the end of this volume.

This book is aimed at people who are enthusiastic about efficient, and renewable, energy technology and wish to apply it effectively, to lower their energy bills and increase their self-reliance. It also addresses people with some technical training who are interested in engineering and design aspects of these technologies, as well as economic concerns.

The book provides:

1. **A starting point, a recommended direction, and where to find further information.** There are roughly 150 references listed and many individuals cited who may be contacted for additional help. (Almost all the references are available at the North Arkansas Community College Library in Harrison, many may be found at the Arkansas Energy Office Library at Little Rock, and some will be found in your public library, so inquire there first of all.)
2. **Pictures, drawings and charts** for clearer understanding.
3. **Recipes** to follow in building or assembling various devices. As with any cookbook, some recipes are better than others or appeal to different tastes. Investigate thoroughly before trying them.
4. **Rough dollars-and-cents evaluations.** Utility bills, estimated pay-back periods, life-cycle cost effectiveness, opportunity costs, trade-offs and other measures of costs vs. benefits are discussed. Economists may quibble, but consumers will get some idea of whether a particular technology or application may be a good investment for them. Because of their uncertain future, tax credits were seldom discussed, although they can be extremely important to a project's viability. There are many considerations, other than economic ones, such as health and safety, long-term durability, and aesthetics, that should be fully explored before undertaking projects such as those described here.
5. **The experiences of others.** The projects reported here were not all model projects. Some were included specifically because of the "how-not-to-do-it" lessons readers could learn from others' mistakes. Projects with different solutions to similar problems were included so they could be compared and contrasted.

These projects were carried out between

1979 and 1983. Twenty-five of the 44 were funded in whole or part by the Appropriate Technology Small Grants Program of the United States Department of Energy and the Arkansas Department of Energy (now the Arkansas Energy Office). Most of the projects report on methods that were "state of the art" at the time they were begun and have been refined since then through experience. Many were clearly experimental and are still being revised.

Often the best sources for up-to-date information in this rapidly-changing field are the various periodicals that specialize in solar, wind, wood and other renewable-energy technologies. Several of these journals are available to the public at the Arkansas Energy Office Library or local libraries.

The Arkansas Energy Office technical staff may be consulted, if necessary, for current recommendations about these technologies.

The federal and state appropriate technology programs served primarily as catalysts. Experiments sparked interest and new ideas; some caught on and spread. According to the poll quoted at the beginning of this introduction, most people are favorably impressed with the idea of solar energy. Now they want to know more about how they can begin to use it themselves and what it will cost. *Achieving Self-Reliance: Backyard Energy Lessons* is offered as an aid in answering those questions.

1 Retrofits for Conservation

Home Renovations Conserve Energy and Use Solar Power to Control Costs

If your household energy costs are too high, you can do something about it. This chapter describes what other Arkansans have done to combat high utility bills.

Conservation comes first. There are two reasons: (1) generally, conservation measures will have a better payback and (2) a solar application won't work unless insulating and weatherizing precedes it.

How do you decide which conservation measures to take? *Tips for Energy Savers* from the Arkansas Energy Office provides a checklist describing measures that offer the greatest return for the least effort and expense.

In other cases, there may be doubt about whether a conservation measure is cost-effective. A Residential Conservation Service audit from your local utilty will analyze various measures and their cost-effectiveness. Undertake retrofit treatments in order of their economic value and payback.

After conservation steps, solar retrofits can be considered. Many treatments are possible and some will be more appropriate at a given site than others. *Solar Retrofit* by Daniel Reif presents a systems selection worksheet for helping the homeowner decide between various solar heating retrofits. If your decision is to be based on dollars saved per dollars invested, then projects in this chapter will be useful.

Residential Passive Solar Application, a publication from the Tennesee Valley Authority, looks at relative retrofit paybacks. Another view of paybacks is found in the article "A Guide to Smart Energy Investments," in *Solar Age* magazine.

Projects by Russell Upham and Harvey Thompson illustrate two different courses taken by Arkansas families.

The Upham retrofit shows that not all retrofit treatments are cost-effective. The replacement of propane, priced at 80 cents per gallon, with electric heat at eight cents per kwh, does not make economic sense, as Upham himself finally concludes. However, the steps he took to improve fireplace efficiency are of considerable interest. The cooling retrofits here were not dramatically effective — if at all.

Harvey Thompson took some very effective steps in reducing cooling costs with thermal chimney and earth cooling tubes retrofits. Thompson's solar greenhouse is integrated with the cooling retrofits and a thermal envelope in a thoughtful manner.

ATTACHED SOLAR GREENHOUSES

The Simmons project represents the nearly ideal situation for a greenhouse retrofit. The Simmons' existing carport was ideal to convert to a greenhouse and the family wanted not just supplemental heat but other benefits of a greenhouse as well. The account of the Trahan greenhouse is based largely on the Albert Skiles monitoring study as reported in *Solar Greenhouse Guide* published by the Ozarks Regional Commission. The payback figures presented there are not especially encouraging, although fuel costs have risen since then.

SOLAR AIR HEATERS

The Arkansas Energy Office no longer advises individuals to construct wood-frame solar collectors, as described in this book. However, the units described in these grant projects represent pioneering. Much work has been done on the design of these units in Arkansas and Missouri. *Simple Solar Air Heaters* by Ron Hughes is particularly recommended as a good reference, especially for site-built collectors. The Office of Human Concern air heater design is representative of several modular collectors which can be built in a workshop.These are active retrofits employing small, cost-effective blowers to increase efficiency. A passive air heater can be built, using detailed plans found

ENERGY CONSERVATION MEASURES

ASSUMPTIONS

The typical Arkansas house is a 1,200-square-foot, wood siding house in Little Rock and is built over a vented crawl space. The house has R-11 insulation above the ceiling, but no insulation in the walls or beneath the floor. The 144 square feet of windows are equally apportioned to the north, east, south and west. It has two exterior doors. The house is centrally heated with natural gas and centrally cooled with electricity. The indoor winter thermostat setting is 70 degrees and the summer setting is 75 degrees.

The costs below are calculated using a natural gas cost of $4.50 per thousand cubic feet and an electricity cost of 8 cents per kilowatt-hour.

TYPICAL ARKANSAS HOME ENERGY BILLS

BEFORE

An ordinary house, little or no insulation, standard heating and air-conditioning equipment.

	Average Per Month
Average total utilities	$117
Low (April and October)	47
High (January and July)	242

AFTER

An energy-efficient house, well insulated, with high-efficiency heating and air-conditioning equipment:

	Average Per Month
Average total utilities	$ 70
Low (April and October)	42
High (January and July)	117

The low figures are not likely to be much lower than stated. The averages and highs are subject to considerable variation (as much as 50 percent) depending upon the individual lifestyle of the occupant(s), number of occupants, and the actual weather encountered.

PAYBACK ON ENERGY CONSERVATION MEASURES

	Cost	Annual Savings	Investment Payback
Caulking and Weatherstripping	$ 80	$ 45	1.8 years
Wall Insulation (R-11 @ 55¢/square foot)	514	190	2.7 years
Floor Insulation (R-19 @ 40¢/square foot)	480	142	3.4 years
Ceiling Insulation (R-19 @32¢/square foot)	384	78	4.9 years
Storm Windows ($5/square foot)	720	77	9.4 years
Water Heater and Pipe Insulation and Water Flow Restrictors	100	54	1.9 years
Total	$2,278	$586	3.9 years

in *Solar Retrofit*. John V. Crone shows how a collector can be situated to heat an area otherwise difficult to heat with solar energy, and then be moved out of the way when it's not needed!

It's important to realize that air heaters are not as efficient as direct-gain south windows with movable insulation. However, these active collector systems offer better control and distribution of the heat. None of these simplified systems incorporate storage, since that adds complexity and is sometimes difficult to retrofit.

BATCH SOLAR WATER HEATERS

These units, also known as solar breadbox heaters, are employed as non-circulating preheaters. Their application is somewhat limited. They are normally mounted on the ground, where shade may interfere. They also may freeze unless drained in winter. As a result they are used seven to 10 months of the year. Despite these limitations, where feasible they are good investments. *Arkansas Solar Retrofit Guide*, and the *New Shelter* article, "The Best We Know: You Can Cut Hot Water Bills by Two-thirds with a Fine-tuned Passive Solar Heater," provide additional background and information.

Hot-water conservation measures should be implemented before use of solar collectors. (See "Tips for Energy Savers" in *New and Improved Energy for Arkansas*.)

Russell Upham Tested Energy Ideas; The Wood Stove Worked; the Water Heater Didn't

Russell W. Upham
13 Basore Drive
Bella Vista, Arkansas 72712
Telephone: 855-3379
Government Grant: $4,500
Experiments in Saving Energy at Bella Vista Showed That Some Worked Better than Others.

BACKGROUND

Russell Upham, a retired mechanical engineer, writes a column titled **The Innovator** for the weekly newspaper at Bella Vista. Some energy-related "innovations" he discussed there are actually in operation inside his energy-efficient house of 1,500 square feet.

Since a fire in the fall of 1976 gutted much of the house interior, Upham has incorporated into his house several devices and treatments, in an effort to heat the house and its water, provide summertime comfort, store heat, and use energy more efficiently.

While many schemes have worked, and some of these have proved cost effective, others have not proved worthwhile. Upham, through observation and some measurements as well as careful record-keeping of fuel usage, has attempted to assess the effectiveness of each.

BUILDING DESCRIPTION AND ENERGY CONCERNS

The two-bedroom house has 1,000 square feet on the upper level and a half-basement of 500 square feet. The house has wood frame construction with walls that have R-11 fiberglass, and a well-insulated cathedral ceiling. The heating system is three-fold:

1. Warm air from a propane-fired stove;
2. electric radiant heating panels; and
3. a wood burning fireplace.

The Uphams do not mind performing many chores daily (such as manually opening or closing insulating devices, etc.) and in very cold weather, they heat only a single area for daytime usage. Russell Upham said that he feels that an "accommodating lifestyle" is an important aspect of effective energy saving.

RETROFIT DESCRIPTION

The following steps have been taken in an effort to cut energy usage:

Interior smoke-damaged paneling was replaced with 6-mil polyethylene (to cut air infiltration) and half-inch gypsum board.

Four types of movable insulation were installed over windows. These included two exterior movable shutters over two picture windows, one quilted roll closure for a third picture window, one set-in closure for a small window with single glass pane and one hinged panel.

The exterior walls of a crawl space — to the north of the half basement — were insulated with two inches of rigid-board insulation.

Every crack that could be an air leak was hunted out and caulked.

A "lean-to" solar greenhouse was added to the south side of the house's lower level. The greenhouse has a double-glazed aluminum frame and measures 7½ by 12 1/3 feet.

Exterior movable insulation panels were added to cut heat loss from the tilted glazing. These also double as reflectors, which provide additional solar gain. Water-filled tanks, sitting under a workbench along the south wall, provide some heat storage.

A "solar room" with 136 square feet of fiberglass glazing slanted at a 75-degree angle was added to the lower level. This area incorpo-

rates three methods of heat storage. In the ground level solar room, a space 13 inches deep by three feet wide is filled with river-washed rock; an equal-sized space contains 21 six-gallon water tanks, plus another 110 gallons of water-filled tanks along the outside solar wall.

Batch solar water-heating units were employed. Initially a homebuilt heater using a single, recycled 30-gallon tank was used. Later, this was replaced by a commercially-built, triple-glazed heater. Instead of the usual reflective surface behind the tank, this one employs a blackened metal surface, which reradiates heat energy to the single tank.

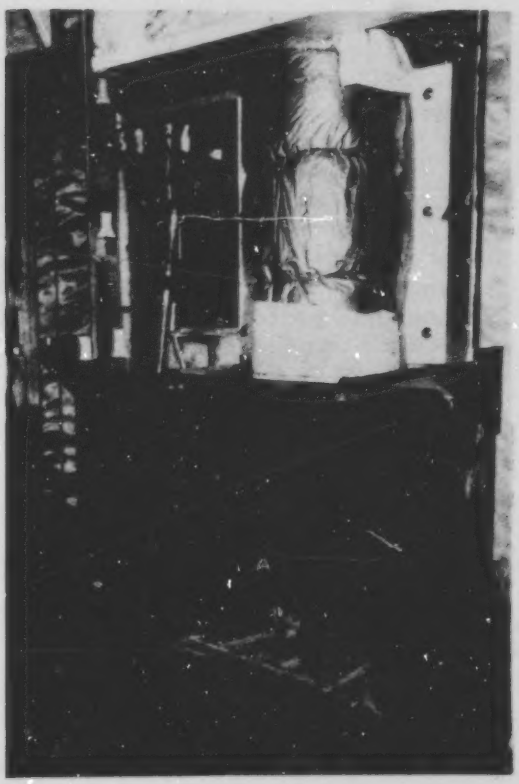
The efficiency and usefulness of a fireplace has been improved. A fireplace water-heating insert provides hot water to a 30-gallon insulated tank sitting inside the mantle-wall above. Because of the tank's location, the heat transfer is by thermosiphon action. When water in this tank reaches 120 degrees Fahrenheit, a 1/100 horsepower pump begins sending some of this heated water into a 120-gallon tank in the basement.

The fireplace gets outside air, channeled through the garage, for combustion.

In an effort to further improve combustion efficiency, experiments on a method of providing forced air to the fire through nozzles have begun.

Experiments using 18 "Thermol 81" heat storage rods, which employ a phase change eutectic salt, were conducted. The rods are 3½ inches in diameter and six feet long.

Upham explored an alternative to using his two-and-a-half ton central air-conditioning system for cooling. This included using a whole-house 1/6 horsepower exhaust fan in the living-dining area, and a roof spray system. The latter



Opening above fireplace (left) conceals 30-gallon storage tank, which Upham hides behind attractive mantel.

was done with a flue nozzle fog-type system controlled by a timer.

Small electric water heaters were installed near the point of intended use. This was in an effort to have more immediate hot water — without a wait — and to minimize piping heat loss. One 10-gallon and two 6-gallon models were used.

Propane furnace heat is being phased out in favor of radiant panel electric heating.

PERFORMANCE AND OPERATING HISTORY

The Uphams' utility bills are perhaps the best measure of the effectiveness of the retrofit treatments. These tables show their seasonal experience and costs:

Winter of 1982

Month	Cost
January	$80
February	$95
March	$55

Fuel Prices Were:

Wood — $60 per Cord
Propane — 80 cents per Gallon
Electricity — 8 cents per Kilowatt-hour

Average monthly usages for the period were 38.3 gallons of propane, 527.3 kilowatt-hours of electricity, and 360 pounds of wood.

For the summer cooling season, the records of Upham electricity usage are of interest:

Electricity Usage in Kilowatt-hours

	June	July	August	September
1980	345	405	916	788
1981	397	640	460	396

The August 1980 electric bill, the highest, was $51.28, based on the actual price of six cents per kilowatt-hour.

A barrier to protect from outside temperature extremes and outside air was desired, and the 6-mil plastic application treatment worked well, according to Upham.

Upham found the movable insulation on the windows to be effective. "The exterior roll-up units, one on the south wall and the other on the west wall of the living-dining area had different effectiveness that we could observe. The closure on the south wall was directly opposite the fireplace, and along with the drape, made a definite difference in 'heat feeling' from the fireplace. It also helps keep out solar heat during the summer. The R value as provided by the manufacturer was 5.

"The west closure seemed to be most effective in reducing surface heat losses due to winter winds. These reductions in heat losses could be verified by taking daily windowsill temperatures, and evaluating them against wind and outdoor temperatures. The interior quilted-type closure is very effective, showing temperature differences across the quilt of as high as 30 degrees Fahrenheit.

"But simplest and least expensive are insertable shutters, either hinged or manually set in place."

"As for insulating the crawl space wall," Upham said, "this raised the temperature in the crawl space about 3 degrees. The over-all effect on raising the 'balance point' for the entire house was virtually impossible to determine. One aspect of this modification was a change from a varying temperature following an outdoor change to a more stable one, indicating the effect of ground temperatures and that heat from the surrounding areas was being captured."

"Caulking and stuffing insulation is, of course, the most straightforward and effective approach to reducing heat losses," Upham said, "but that didn't entirely satisfy me. Until I built and installed insulated closures on the solar greenhouse, the net effect was more heat loss (through the glazing at night) than heat gain (during sunlight). With the closures in place during the past winter, no additional heat was required."

The greenhouse temperatures ranged from 50 to 58 degrees with outside temperatures ranging from lows of 18 to 30 degrees.

"Opening and closing the closures is a chore," Upham said, "but with some minor additional modification, the greenhouse should be entirely solar-heated with some contribution to the over-all energy saving for the house."

Upham concluded, "A solar room can be a

marvelous place for a hot-tub, but doesn't do much for over-all heating without some mechanical means of moving the warm air to other parts of the house."

As for the storage in ths area, Upham determined that the amount is too much, given the glazing area, and that heat transfer from storage to the room is too low. He added:

"One interesting aspect was the **Solar Room temperature never dropped more than one to two degrees below 60 degrees Fahrenheit** with outside temperatures as low as 10 degrees.

"Using a blower to induce a greater amount of heat to the storage space showed little effect. The same was true with my attempts to use the storage for summertime cooling. The conclusion was that summertime temperature differentials were too small to effect sufficient cooling to make the system practical."

Upham questioned whether batch solar water heating during the winter months in northwest Arkansas is practical. During the summer the batch heater can be adequate.

Reflective panels covered with foil send extra sun into Upham's greenhouse.

Upham said "My first attempt at batch type water heating wasn't successful. We simply have too many leafy trees in the summer and not enough solar radiation hours to provide adequate hot water heating with a single tank heater during the winter.

"I was crowded for both space and location where trees didn't adversely affect the solar heat input," Upham continued. "Night losses from the tank plus piping losses were too great to produce a usable system during the winter. The daytime losses due to trees was too great in the summer."

"My wood burning project went in two directions," Upham said, "which in effect were directly opposing each other.

"On the one hand," he said, "I was developing and using a method of firing in the fireplace that produced a phenomenal amount of radiant heat to the room while burning a minimal amount of wood."

"On the other hand," he continued, "my designed water heating insert to scavenge heat was trying to heat water for overnight storage. The former was so successful the latter didn't produce the expected amount of heated water."

Lacking the needed instrumentation, it was impossible to determine the actual improvement in burning efficiency. The fireplace generally operated from 6 to 9 p.m. and quite often from 6 to 8 a.m. It produced all the heat necessary to maintain acceptable comfort in living.

The water heating insert heated the 30 gallon beside-the-fireplace tank to 120 degrees about twice during an evening and once in the morning. The initial warm-up would be from about 80 degrees and the reheat from 100 degrees, while burning about 15 to 18 pounds of wood.

Regarding his application of the phase change rods, Upham commented, "It takes temperatures of over 100 degrees Fahrenheit to melt the salt and the 81 degree change-back temperature is too low to be effective."

The roof spray system was plagued by problems with widely-fluctuating water pressure and, during extreme heat and drought, with bans on extra water usage. Upham said that he doubted if it would ever be cost-effective.

He said, "The use of the wide-blade ceiling fan is very effective, both when using and not using air-conditioning." The electricity usage is sufficiently low to allow for extended periods of operation. This is not true for the 1/6 horsepower exhaust fans. A two-stage operation is most effective. The first stage would be the "evening cool off," by running the fans from 10 to midnight to dissipate the heat built up in the house during the day.

The second stage would operate from 5 to 6:30 or 7 a.m. to chill the house's mass for daytime holdover. Further cooling by air-conditioning can provide for sufficient holdover storage to allow for only ceiling fan operation during the normal peak electricity load period.

Because of the house design, which has a very low pitched roof, the use of an attic exhaust fan was virtually impossible. Exhausting air through the basement can and will cause humidity problems in the basement area and at times in the living area. The result is mildew and objectionable odor.

Upham said, "As yet I have found no reasonably acceptable solution for either."

Upham now says that he has mixed feelings regarding his earlier plans and commented, "Phase-out of propane gas for heating in favor of an all electric unit, where the structure wasn't originally designed for it, is a highly-questionable modification."

COSTS AND BENEFITS

The 1980-1983 phase of Upham's efforts was funded by a $4,500 grant. The Upham house has become more energy efficient as a result of energy-related retrofit treatments, but a "before" and "after" analysis with respect to energy savings has not been attempted. It is possible that the project increased the value of his property; Upham concluded, "I doubt that I have enhanced the saleable features of this house with this project. Most people are looking for homes that are reasonably energy-efficient and simple to operate. They aren't willing to perform 'chores' in order to reduce energy usage or costs."

As Upham's earlier comments indicate, his retrofit steps have included both successes and failures. Certainly he has learned a great deal about household energy efficiency. Upham today would do things differently, partly due to new energy-related product developments.

"If I was to apply for a grant in the same amount ($4,500) now," Upham said, "my first major expenditure would be to replace the existing standard 1969 propane furnace with a current high-efficiency unit and field-test it. This would be followed by a more limited attempt to reduce the heat losses from the structure."

He continued, "My second major expenditure for a retrofit project would be a 'solar assist' heat pump water heater."

Monitored operation of such a unit could produce the means for greatly improving upon straight solar heating of domestic water in low and moderately-low-income homes, Upham suggested. Packaged types can reduce installation costs and generally enhance the over-all operation.

Upham said that he would also "phase out the old low-efficiency appliances for higher efficiency ones."

Thermal Envelope and Cooling Tube Improved Energy Bills at One Fairfield Bay Residence

Harvey and Betty Thompson
Route 2, Box 290
Fairfield Bay, Arkansas 72088
Telephone: 884-6545
Government Grant: None
A Sunspace-charged Thermal Envelope and Thermal Chimney Fed by a Cooling Tube Were Retrofitted to an Existing Home.

BACKGROUND

The Thompsons moved to Arkansas in 1980 into a 1,100-square-foot home they had just bought. Fueled by community college courses in active and passive solar energy they attended in Iowa, they began a project to retrofit their home with a thermal envelope and a cooling tube. By the summer of 1980, the sunspace windows had been installed, and by mid-1981, the envelope addition was largely complete. By the summer of 1982, the cooling features were in place. The goal was to bring down high utility costs about which the Thompsons and their neighbors had been complaining.

Harvey Thompson wanted to assess the effectiveness of the steps he'd taken, so he began a detailed analysis of his utility bills. He also began collecting information from neighbors who lived in similar-sized all-electric homes -- those who weren't benefiting from any energy-saving retrofit.

BUILDING DESCRIPTION AND ENERGY CONCERNS

Their all-electric home is on a sloped site with ground-floor doors on several levels. The walls are insulated with three and a half inches of fiberglass and windows on east and west have single panes.

Before the retrofit, the attic was plagued with high summer temperatures and the basement with high humidity.

The electric heat comes from a resistance heat furnace, and there is a central air-conditioning system.

Mr. and Mrs. Thompson increased their living space and reduced their utility bills at the same time.

RETROFIT DESCRIPTION

A two-story sunspace measuring 6 × 30 feet was added to the south side of the house. Ten 5 × 5-foot double-glazed windows — five on each level — provide 250 square feet of passive collector on the vertical south wall.

The sunspace heat can be routed into the thermal envelope. This was provided by adding more insulation to the ceiling. It now has from 6 to 10 inches of fiberglass. They also added insulation to the roof — up to 18 inches in places. Another wall was added to provide a double wall on the north side.

The envelope consists of the ceiling-roof space and north wall, with a through-the-basement return to the sunspace. The air flow through the envelope is passive; there is no fan.

A 40-foot-high thermal chimney was added in the sunspace. It is made of plywood. The unglazed upper section extends eight feet above the sunspace roof.

The intake air for this is supplied by a 60-foot-long cooling tube 15 inches in diameter. It is buried seven feet below the ground. The tube is plastic culvert pipe with holes drilled in it to relieve condensation build-up.

PERFORMANCE AND OPERATING HISTORY

For winter heating, the Thompsons spent an average of $190 on electricity in 1982 and 1983. In the historically severe winter of 1984, their heating cost for the season was $275, compared to many neighbors' costs of $400 to $700.

In 1984 the Thompsons added movable insulation to the lower level of windows to cut night-time heat loss. The shutters also serve as reflectors during the day.

For cooling, the thermal chimney performance has been very good. The draft coming out of the top of the cooling tube is reportedly quite impressive.

Harvey Thompson said that he had mixed feelings about the cooling tube. He suspects that the thermal chimney would cool the house nearly as well if the air coming in a basement screen door were utilized for intake.

However, he points out that the cooling tube supplies air 10 degrees to 15 degrees cooler for intake than would otherwise be the case. This combination cooling system has reduced attic temperatures markedly. Ninety-nine degrees was the highest recorded. The system has reduced high summer humidity levels in the basement. It has also resulted in lower cooling cost: $17.30 in 1982 and only $58.50 in 1983.

A high of 480 kilowatt-hours was needed for air-conditioning in August, 1983. The passive cooling retrofit keeps the house comfortable by itself until the outside air temperature reaches 92 degrees, beyond which air-conditioning is needed.

Combining reduced heating and cooling costs with the other electrical needs of this all-electric home has led to reduced electric bills. In 1982 the annual electricity cost was $609, for 9200 kilowatt hours used, or $50.57 per month.

COSTS AND BENEFITS

About $6,000 has been invested in this retrofit addition to the house. Besides increasing thermal comfort and providing additional living space in the solarium, the Thompsons have saved money in reduced utility costs.

Harvey Thompson estimates that neighbors typically spent $500 per year on heating, compared to his $190, and $500 per year on cooling, compared to his $38 annually, based on the average of 1982 and 1983.

Taking those figures, the Thompsons save $772 per year on heating and cooling costs. A simple payback calculation, which ignores rising utility costs, shows the Thompsons will recoup the investment in 7.8 years. No value was assigned to the additional living space of the solarium, but that has value in comfort that should not be overlooked.

Greenhouse at Dover Supplies Winter Heat and Vegetables to the Simmons Family

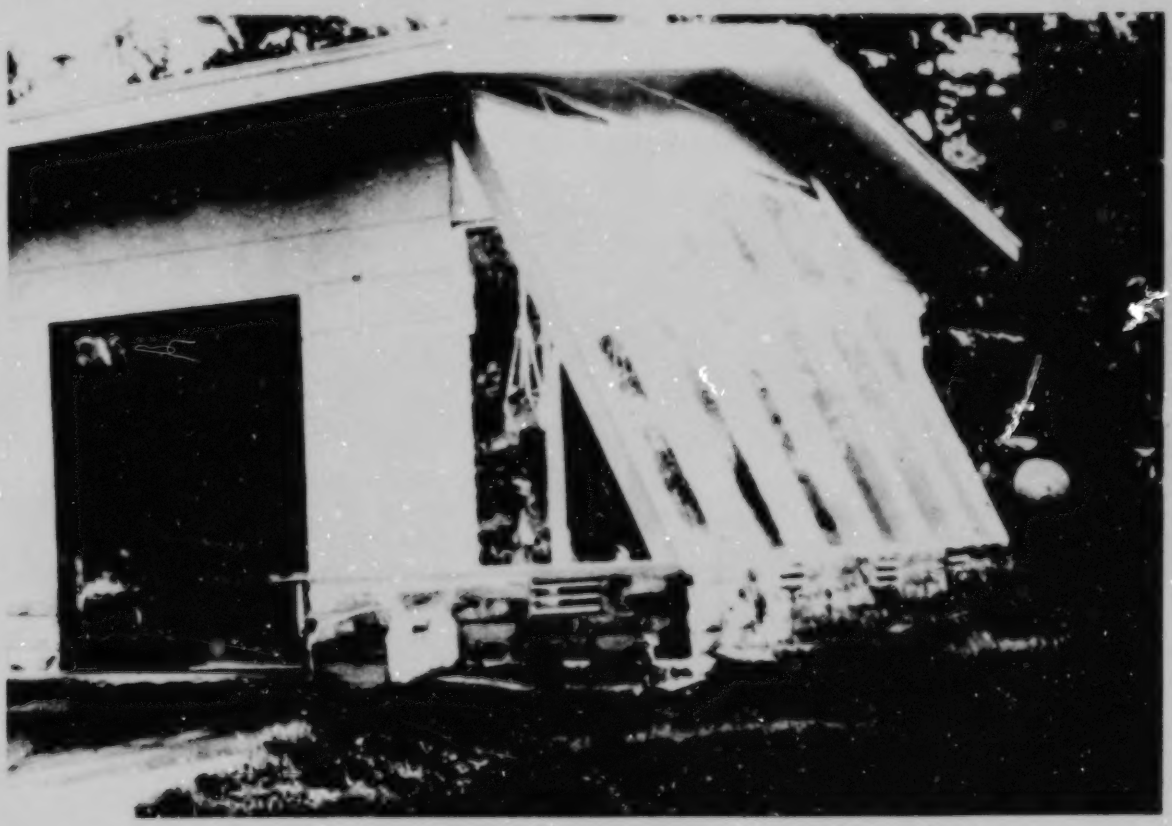
Joy and Larry Simmons
Route 2
Dover, Arkansas 72837
Phone: 331-3265
Government Grant: $900

The Greenhouse Was Created from the Family Carport to Improve Comfort, in a Weatherization Effort.

BACKGROUND

After suffering through the record-setting heat wave of July, 1980 in a poorly-insulated house, the Simmons family decided to do something about it. By the end of the summer, they had spent $250 for blown-in fiberglass insulation. With their house properly insulated and weatherized, the Simmons looked to the sun for some help with winter heating and gardening.

By the winter, they converted an existing 16½ × 12-foot carport on the south corner of their home into a solar greenhouse.



This greenhouse helps control energy bills for the Simmons family; once, it was a carport.

BUILDING DESCRIPTION AND ENERGY CONCERNS

The house has 859 square feet of heated living space and is insulated with 3½ inches of fiberglass in the walls and 6 inches of fiberglass in the ceiling. The common wall between greenhouse and house was left uninsulated. A woodstove serves as the house heating system.

The old carport was extended on one end by four feet and turned into a greenhouse measuring 265 square feet. The attached greenhouse is 16½ × 16 feet. There is 144 square feet of glazing oriented roughly 10 degrees to the east of south and tilted at a 60-degree angle.

The double glazing was site-built. The panels were fashioned from 34 × 76-inch and 34 × 32-inch tempered glass sheets. Heat storage is provided by a rock bed measuring 2 × 4 × 16½ feet, which contains five cubic yards of rock.

Planting is mostly in wooden tubs.

Supplemental heat to the house is delivered from the greenhouse by means of a small ceiling fan placed in a former air-conditioning opening measuring 16 × 26 inches.

Summer ventilation is provided by five wall vents measuring 8 × 16 inches each, which give a total of 4½ square feet, in the kneewall; by two vents in the east and west wall, totaling three square feet; and by a 3 × 6.7-foot sliding patio door, which provides 20 square feet. The glazing can be shaded in summer by a fold-down polyvinyl shade cloth, which lets 70 percent of the light through.

The east and west walls are of 2 × 6 frame construction and insulated to a value of approximately R-25. The cement-block kneewall is insulated inside and outside with one-inch Styrofoam.

The ceiling is insulated to R-20 in a manner similar to the rest of the house.

The foundation is a 6 × 12 inch poured concrete reinforced beam with two inches of Styrofoam on the bottom and outside of the footing. The floor is concrete.

PERFORMANCE AND OPERATING HISTORY

The Simmons family reported in an October, 1983 interview that the greenhouse has performed satisfactorily since its completion in December, 1980. It has furnished some supplemental heat to the house on sunny days and has proven to be an ideal environment for growing plants.

Spot temperature monitoring has shown that greenhouse temperatures remain well above freezing, despite very harsh weather. For example, on February 11, 1981, the temperature dropped to 0 degrees Fahrenheit and a 30 mile-an-hour wind created a wind-chill factor of minus 35 degrees, yet the greenhouse dropped only to 42 degrees.

Lettuce, radishes, carrots, tomatoes, squash, cauliflower, broccoli, spinach, and houseplants have all thrived. Insects have been kept under control by letting predators such as spiders and frogs live in the greenhouse.

The summer shadecloth, shade trees and ventilation have held down summer greenhouse temperatures to the mid-80s. Without the shadecloth, 110 degrees was once recorded.

COSTS AND BENEFITS

The entire conversion project cost just under $1,200. Besides providing supplemental heat, a place to grow plants, and an additional pleasant living space, the greenhouse has served as a place to store and dry firewood for the woodstove.

Solar-energy Professionals Study Greenhouse Attached to J.D. Trahan Home

J. D. Trahan
Route 3
Huntsville, Arkansas 72740
Government Grant: None
The International Solar Energy Society Studied This Solar Greenhouse at Huntsville.

BACKGROUND

Trahan's greenhouse was featured at an international meeting of professional solar-energy designers and sellers. In 1979, Albert Skiles, a Fayetteville architect, presented a technical paper at a session of the International Solar Energy Society during the annual meeting in San Diego, California.

Entitled *Performance of Attached Solar Greenhouses in the Ozarks*, Skiles' paper depended upon temperature monitoring data gathered at the Trahan greenhouse from November 26, 1978 to January 7, 1979.

The data was taken with two continuous graph temperature recorders and several hand held thermometers.

BUILDING DESCRIPTION AND ENERGY CONCERNS

The greenhouse was designed to provide both supplemental heat and a place to grow additional food for the Trahans. The heat is vented into the kitchen of the adjoining farmhouse.

SOLAR RETROFIT DESCRIPTION

This 8 × 14 foot greenhouse has 117 square feet of double glazing. Of this, 74 square feet are tilted and 43 square feet are in the vertical kneewall. The outer glazing layer is tempered glass. Panes measuring 28 × 76 inches were used for the tilted portion. The inner layer is clear vinyl (Warps Flex-O-Glass 9mm thick). Heat storage is provided by 15 water-filled barrels. Each barrel holds 55 gallons.

An eight-inch thermostatically-controlled duct fan, which provides 150 cubic feet per minute, is used for heat delivery to the house.

The greenhouse is of 2 × 6 frame construction insulated to a value of R-19 in the walls and ceiling and to R-8 along the oak railroad-tie foundation perimeter. Two-inch rigid-board movable insulation panels cut heat loss at night.

In summer the kneewall glass panes can be replaced by screen frames for ventilation.

PERFORMANCE AND OPERATING HISTORY

The Trahan greenhouse succeeded in maintaining plants all through severe winter weather, according to a 1980 interview, and supplied a projected 2.1 million Btu's of heat to the Trahan house.

According to Skiles, this is about 12 per cent of the total heat an adequately-insulated house would require. The calculation assumes the home has insulation of a value of R-11 in the walls and floor, and R-19 in the ceiling. A typical 1,800-square-foot house in Northwest Arkansas is the basis for the figure.

During the winter of 1978-1979, two monitoring studies were performed in this greenhouse. **First** the effect of **changing the thermostat setting of the heat delivery fan** was studied. The performance in Figure 1 was obtained with FAN CONDITION A: on 75°, off 70°. Results listed in Figure 2 were obtained with FAN CONDITION B: on 85°, off 80°. On sunny days, CONDITION A averaged 5 hours, while in CONDITION B, the fan came on for only an average of two hours.

CONDITION A resulted in an average 16,200 Btu's per day delivered to the house, compared to 9,720 Btu's per day for CONDITION B. CONDITION B produced only slightly higher

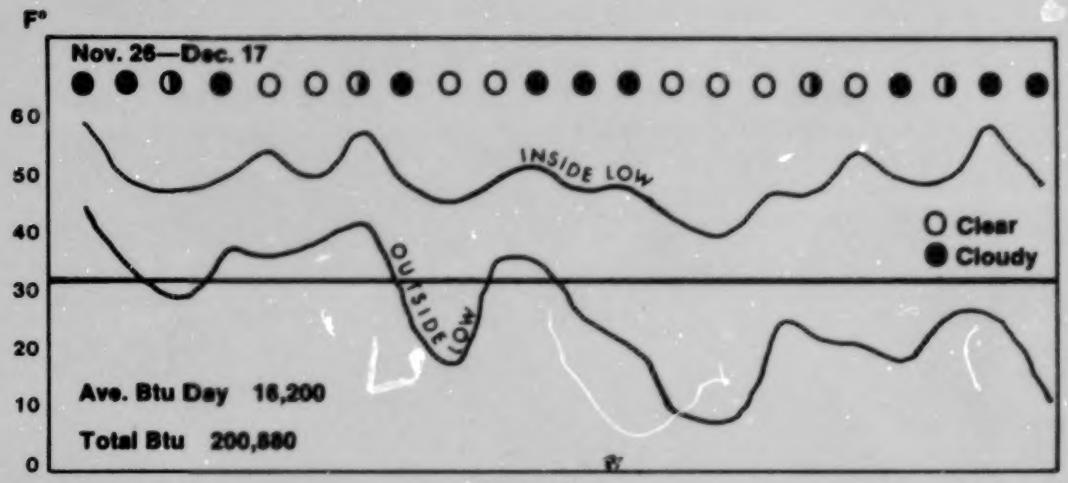


Figure 1

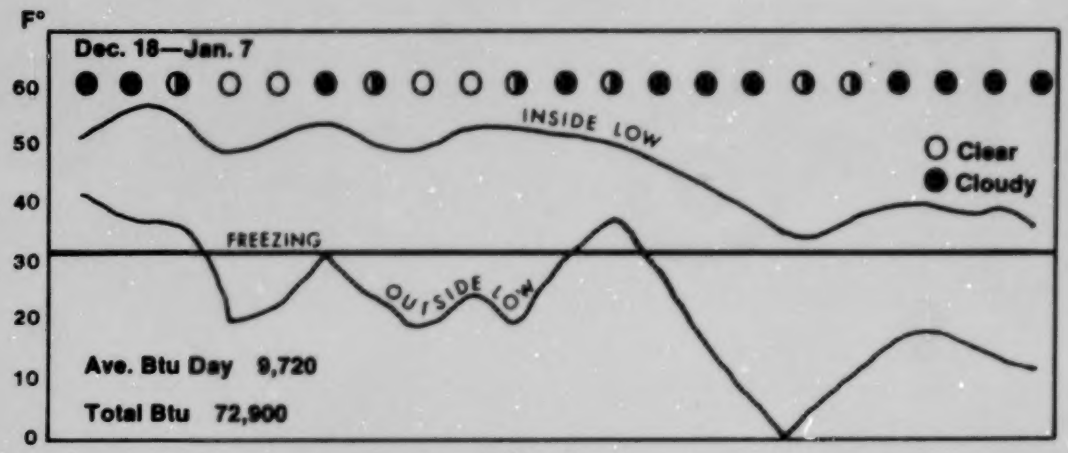


Figure 2

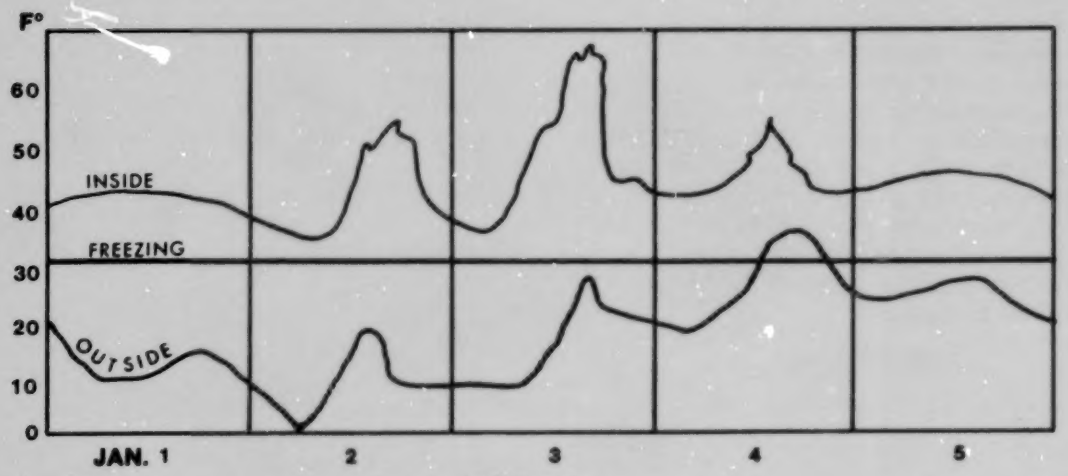
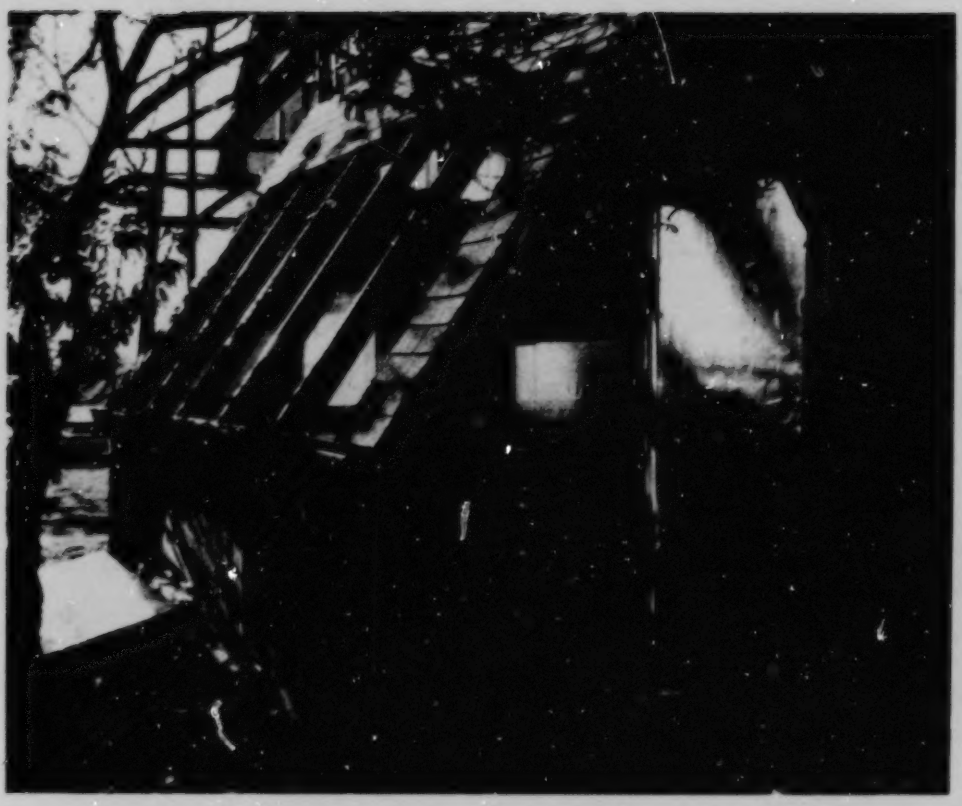


Figure 3



J.D. Trahan used simple materials to build this greenhouse on his Madison County home.

night-time temperatures than CONDITION A, yet heat delivery to the house was reduced by 40 percent.

Second, the performance of the greenhouse in **very cold weather** was studied. See Figure 3. A stretch of three cloudy days followed by below-zero nights from January 5 to January 8 dropped the greenhouse to 32 degrees briefly on the morning of January 8. One casualty of this was a tomato plant; everything else fared well.

On cloudy days in the 10 to 20-degree range, the greenhouse interior temperature did not drop, showing that diffuse solar gain at least equaled the heat lost.

COST BENEFITS

Materials cost $425 in 1978. The estimated 2.1 million Btu's of supplemental heat provided by the greenhouse has a value of $49, based on replacing electric heat costing eight cents a kilowatt hour. The value would be $14.50 if the greenhouse heat replaced natural gas costing 45 cents per therm and burned at 65 percent efficiency.

Simple payback times — assuming free homeowner labor, a similar materials cost today, no tax credits, no escalating fuel costs, no credit for the extra benefits of the space, the food, etc. — are 8.7 years for electric heat and 29 years for natural gas.

Sun-heated Metal Roof Supplies Both Hot Water and Cooling to the Rimkus Home

Thomas W. Rimkus
Route 3, Box 184 A
Huntsville, Arkansas 72740
Telephone: 559-2863
Government Grant: $1,405
A Retrofit Provides Solar Water Preheating and House Cooling to This Home in Huntsville.

BACKGROUND

Tom Rimkus installed a system to heat water and cool his house. Although lack of funding hampered Rimkus' refinement of his system, the concept did demonstrate some promise.

Speculations of some refinements to the basic system are presented at the end of this project narrative.

BUILDING DESCRIPTION AND ENERGY CONCERNS

The 1,000-square-foot house has wood-frame construction with 3½ inches of fiberglass insulation in the walls, and six inches in the floor and roof. The south-facing shed has a roof with a 3/12 pitch (17 degree tilt). It measures 1,050 square foot.

A spring is up the hill from the house so gravity-flow water is available. A wood stove is used to heat the house and electricity is used to heat the water.

RETROFIT DESCRIPTION

After carefully sealing the existing roof against leaks, a second, unpainted galvanized steel roof was installed over the first. This was done by attaching metal hangers and using these to secure 2 × 4 pine rafters and 1 × 4 oak purlins, to which the roofing was nailed.

A length of ¾-inch black polyethylene pipe was attached along the ridge of the roof and perforated with a 6-penny nail, at intervals matching the roof corrugations.

Gravity-flow water was brought from the spring to the roof. It proved to have pressure of 50 pounds per square inch. The water was permitted to trickle down the roof corrugations. A single gutter and screened downspout catch the water and direct it to a heat exchanger.

The exchanger is an insulated 55-gallon drum with a 20-gallon water tank inside. Six inches of fiberglass was used to insulate the exchanger. The water off the roof fills the drum to a certain level and then the coldest water — from the bottom — goes out the pipe.

Different operations are used to obtain the best results for heating water and for cooling the house, and when the system is doing one task well, it performs the other less efficiently.

In fact, cooling is most efficient when the system has a slow rate of flow and there is a continuous trickle of water on the roof that almost evaporates, leaving little hot water for collection.

Preheating water works best when a sudden heavy flow of water quickly retrieves the roof's built-up heat. The short duration of this minimizes evaporation and heat loss.

Rimkus decided to develop a two-mode system. For three-hour periods in the middle of sunny days, the system works in the "preheat mode" and at other times, it is in the "cooling mode."

The "preheat mode" required some engineering, and Rimkus developed a spurt tank system.

"The spurt tank included a pressure switch on the tank," Rimkus said, "and a snap disk temperature sensor on the collection surface of the roof. In the system, a 24-volt solenoid valve opens when the pressure in the spurt tank reaches a pre-set level and the roof

reaches a certain temperature. This allows the pressure tank to unload its water onto the roof in a spurt.

"When the pressure in the spurt tank reaches the low setting on the pressure switch," Rimkus said, "or when the roof temperature drops below the low setting on the snap disk, the valve spurts and the pressure tank is allowed to refill at a rate determined by a valve in the line from the spring."

He continued, "The cycle time between spurts is determined by the rate at which the tank is allowed to repressurize by the high and low settings on the pressure switch and by the rate at which the roof can be re-heated by the sun."

To further encourage cooling, the space between the two roofs was left open to enhance air movement. Because the existing shed roof possessed substantial screened upper and lower vent openings, there was another "draw chamber" to aid in house cooling.

PERFORMANCE AND OPERATING HISTORY

The system has no glazing and is clearly for summer use only.

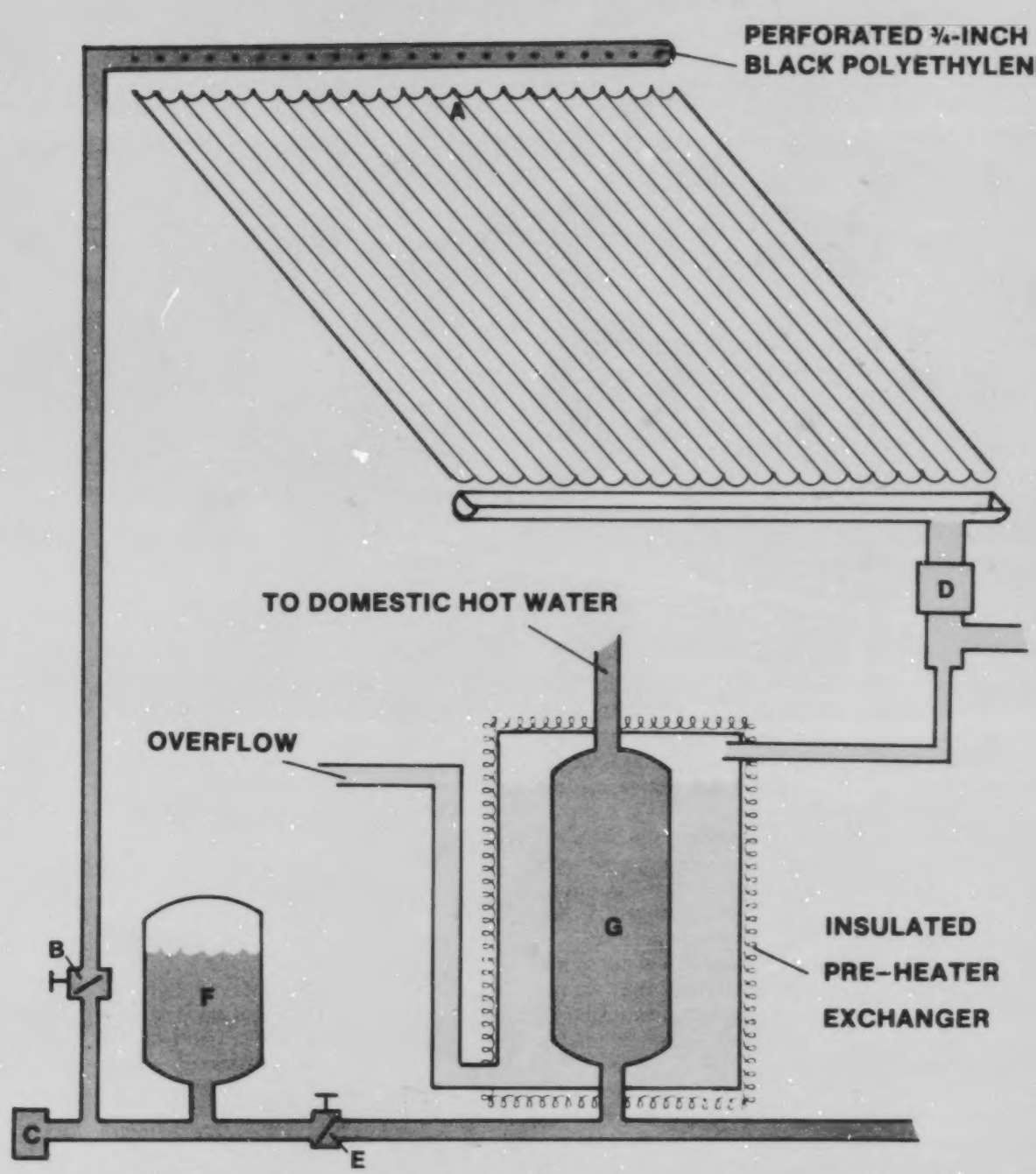
Unfortunately, the Rimkus system has been plagued by summertime droughts and lower-than-expected flow from the spring. The insufficient flow hampered adequate testing of the "cooling mode".

Separating the effect of the trickling water's cooling from the effect of air-chamber cooling is difficult in any event. With just the air cooling in place, tests conducted between July 5 and July 13, 1980, show outdoor average temperature fluctuations from 63 to 98 degrees and indoor fluctuations from 66 to 85 degrees.

The "preheat mode" has been tested more thoroughly, between July 13 and July 15, 1980. Temperatures in the preheater were measured

PRE-HEATER TEST CHART

Date	**7/13**	**7/14**	**7/15**
Ambient Water Temperature	**75**	**75**	**75**
Preheater Temperature:			
Initial	75	89	87
Final	100	98	100
System Timer:			
On	12 p.m.	1 p.m.	1 p.m.
Off	3 p.m.	3 p.m.	3 p.m.
Water Pressure; Pounds per Square Inch	50	50	50
Pressure Switch:			
On	42	42	42
Off	23	23	23
Cycle Time Seconds	23	23	23
Gallons per Cycle	.28	.28	.28
Snap Disk Settings:			
On ° F	130	130	130
Off ° F	110	110	110
Preheater Drained?	Yes	No	No



A ROOF TEMPERATURE SENSOR

B SOLENOID VALVE

C PRESSURE SWITCH

D FILTER

E VALVE TO IMPEDE FLOW TO SPURT TANK

F SPURT TANK

G PRE-HEATER TANK

Diagram shows operation of the Rimkus system.

Rimkus used this system to combine spring water and the heat of a tin roof for hot water and cooling.

before and after the spurt system was on.

Rimkus said that on July 13, 1980, 0.28 gallons of water was delivered at a cycle time of 28 seconds for three hours, raising the temperature of 20 gallons of water in the preheater from 75 to 100 degrees.

Twenty-two hours later, after three showers and some dishwashing, the preheater showed a temperature of 89 degrees. The temperature of the preheater water was returned to 98 degrees, with only two hours of spurting.

On all three days of testing, the water in the preheater was warmed enough for shower use. The household water heater boosted the temperature of the water from the preheater for dishwashing.

On July 15, 1980, Rimkus reported, the exchanger, which was at an initial temperature for the day of 87 degrees, was drained before the system was turned on. During the two-hour period, the spurt system raised the temperature in the preheater to 100 degrees.

COSTS AND BENEFITS

The project was financed by a grant for $1,405, which went mostly for materials.

The project benefits are viewed chiefly as research that will help others refine the system into a more practical one. The Rimkus family used the system (chiefly the preheater) for many months, according to an October, 1983 interview, although it is no longer in operation.

The additional air chamber created by the double roof has helped with house cooling.

Rimkus and others have ideas for refining the system to make it more efficient and perform other tasks. These include:

- Painting the roof a dark color
- Adding a layer of glazing over the roof, perhaps cheap polyethylene that could be removed in summer
- Using heated air from the air chamber in winter
- Using the double roof air chamber to pull hot air out of the house in thermal-chimney fashion
- When adding a double roof, also incorporating an envelope-type retrofit

Rimkus said that he believed the "spurt system" he developed could work well in other solar collectors.

Northwest Arkansas Residents Learned How to Make Solar Batch Water-heaters

Northwest Arkansas Economic Development District, Inc.
Highway 62-65 North
Box 668
Harrison, Arkansas 72601
Telephone: 741-5405
Government Grant: $3,000
Solar Batch Water-heaters Were Demonstrated at Workshops at Harrison and Huntsville.

BACKGROUND

The program instructors and the supervisors were Allen Grogan and Larry Berry. Dozens of youths aged 16 to 23 working in the Comprehensive Employment and Training Program (CETA) program were employed.

This batch solar water-heater is the same as 65 similar units installed at Harrison alone. In addition, solar greenhouses, solar ovens, flat-plate collectors, solar air-heaters, window-box greenhouses, and solar food-dryers were built at the two workshop locations.

In 1979, Allan Grogan designed a double-glazed batch solar water-heater, with two tanks, which employed Kalwall glazing five feet wide, and required 2½ sheets of plywood to build.

Dozens of these were installed — free of charge — on the homes of low-income, elderly residents. Still others were sold at a cost that only paid for materials, around $250.

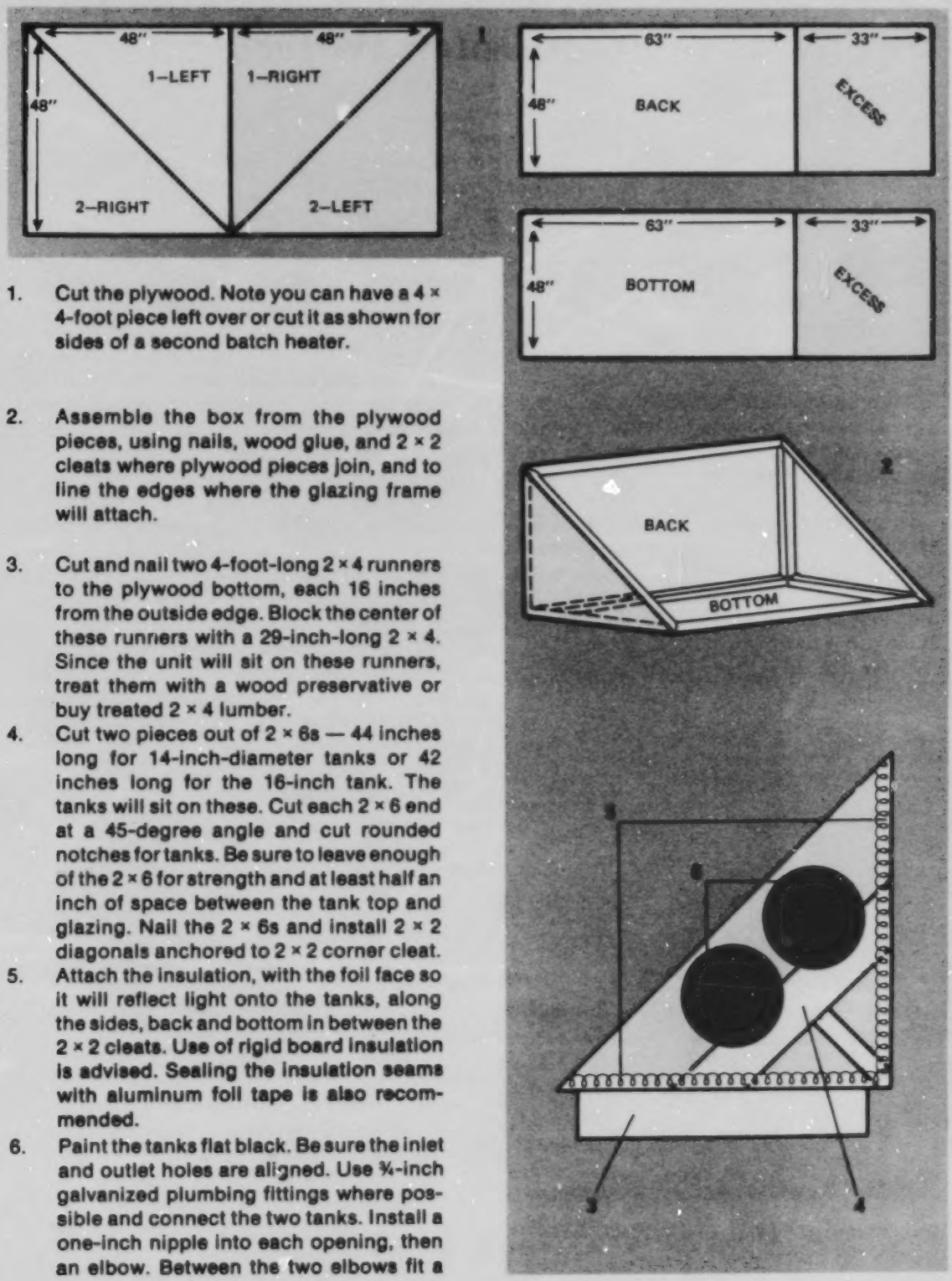
The use of fiberglass glazing is well-suited to yard locations where playing children and glass might not mix. However, since the five-foot wide glazing employed here is usually sold in minimum quantities of 25 feet, this may present problems to builders of single units, who will not need that much.

MATERIALS

For one batch solar water heater the following are required:

QUANTITY	ITEM
3 sheets	Half-inch AC exterior plywood, measuring 4 × 8 feet each
30 feet	2 × 4 lumber
61 feet	2 × 2 lumber
8 feet	2 × 6 lumber
2	30-gallon hot-water tanks
10 feet	Kalwall glazing, 5 feet wide
40 square feet	3½-inch fiberglass insulation or two 1½-inch foil faced rigid insulation boards, 4 × 8 feet (Thermax, Technifoam, etc.)
4 tubes	Silicone caulk
	Flat black paint
	Miscellaneous plumbing supplies (¾-inch galvanized fittings, copper tubing, pressure relief value, plumber's tape etc.)
	Miscellaneous hardware (nails, screws, etc.)

PROCEDURE



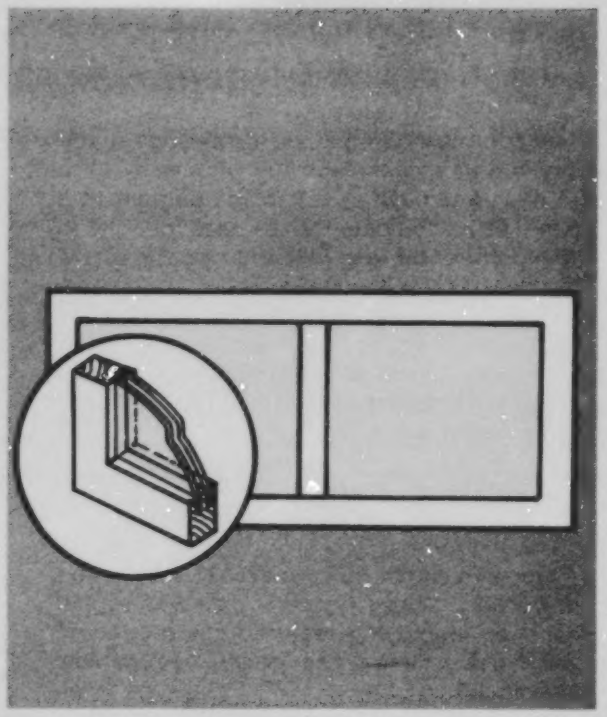
1. Cut the plywood. Note you can have a 4 × 4-foot piece left over or cut it as shown for sides of a second batch heater.

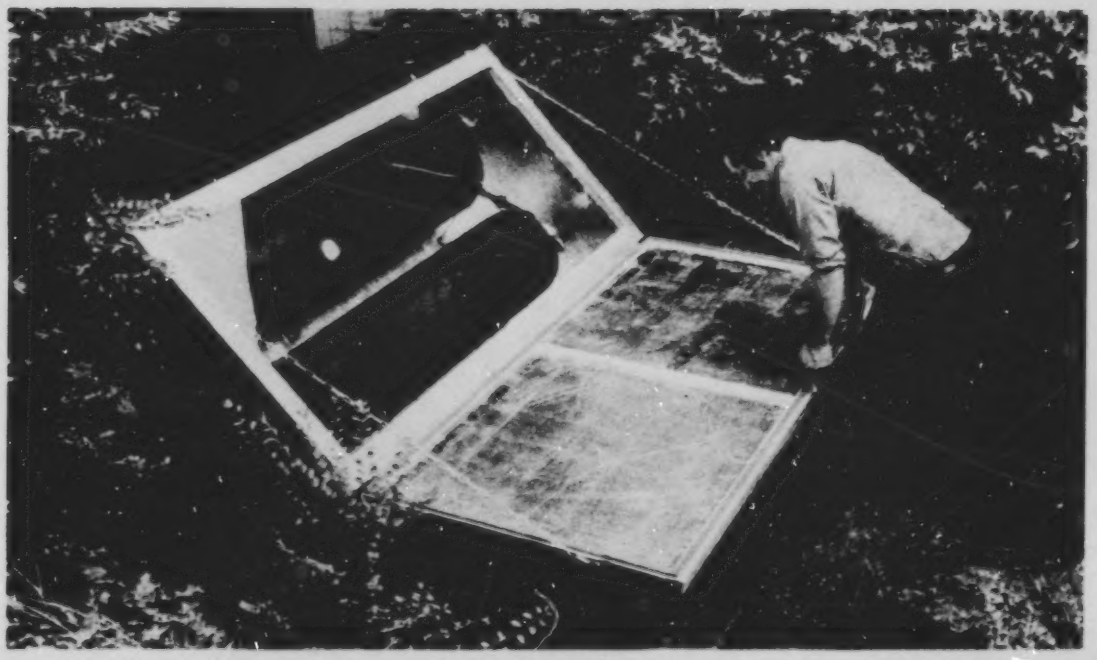
2. Assemble the box from the plywood pieces, using nails, wood glue, and 2 × 2 cleats where plywood pieces join, and to line the edges where the glazing frame will attach.

3. Cut and nail two 4-foot-long 2 × 4 runners to the plywood bottom, each 16 inches from the outside edge. Block the center of these runners with a 29-inch-long 2 × 4. Since the unit will sit on these runners, treat them with a wood preservative or buy treated 2 × 4 lumber.
4. Cut two pieces out of 2 × 6s — 44 inches long for 14-inch-diameter tanks or 42 inches long for the 16-inch tank. The tanks will sit on these. Cut each 2 × 6 end at a 45-degree angle and cut rounded notches for tanks. Be sure to leave enough of the 2 × 6 for strength and at least half an inch of space between the tank top and glazing. Nail the 2 × 6s and install 2 × 2 diagonals anchored to 2 × 2 corner cleat.
5. Attach the insulation, with the foil face so it will reflect light onto the tanks, along the sides, back and bottom in between the 2 × 2 cleats. Use of rigid board insulation is advised. Sealing the insulation seams with aluminum foil tape is also recommended.
6. Paint the tanks flat black. Be sure the inlet and outlet holes are aligned. Use ¾-inch galvanized plumbing fittings where possible and connect the two tanks. Install a one-inch nipple into each opening, then an elbow. Between the two elbows fit a

length of ½-inch copper tubing and install it with compression fittings. Install a pressure-relief valve on the upper tank. Use plumber's strap to fasten the tanks to the 2 × 6s.

7. Build the glazing frame out of 2 × 4s with a center 2 × 2 support. Note the top and bottom plywood edges will need leveling at a 45-degree angle before the frame is attached. The upper and lower 2 × 4s will need grooves cut for the glazing. Follow manufacturer's instructions for installing the Kalwall glazing, and seal it with silicone caulk. Wait until the glazing has been installed before nailing the bottom of the frame. Installing the glazing with screws, so that it can be removed later if necessary, is recommended. Single glazing instead of double glazing may be used with this design.
8. The unit is plumbed to the existing water heater. Pipes running to and from the batch heater should be insulated to a value of R-4; use waterproof insulation.





Paul Balmuth of the Arkansas Energy Office opens the reflective cover of a functioning Sun Mummy unit. When opened, the tanks of water are heated by direct sunlight and reflected sunlight from the cover. The length of the chains on each side of the heater can easily be adjustd to re-position the cover as the seasons change.

PERFORMANCE AND OPERATING HISTORY

According to Grogan, on the average sunny day, the water will reach 100 degrees by 10 to 11 a.m., and peak at 125 to 135 degrees at 3 p.m. The batch heater can be used for eight to 10 months of the year, depending upon where in Arkansas it is employed.

Normally, the tanks will be drained in winter to prevent freezing. An insulating/reflecting cover can improve performance, as can a pattern of heaviest hot-water use in afternoon or early evening.

COSTS AND BENEFITS

One unit can be built for $250 to $300, using new tanks. These typically cost $50 to $60 each, so employing recycled gas or electric water-heater tanks can greatly reduce this investment.

Any used tanks should first be pressure-tested for leaks. By using the solar batch-heater, annual water-heating costs can be reduced by 40 percent or more for a typical household. Payback periods of one to four years can be expected.

Contact Allan Grogan at Delmar Route, Harrison, Arkansas 72601, or telephone him at 741-2129 for more information.

Sun Mummy Built at Dumas Workshop

In the summer and fall of 1981, the Desha Energy Management Advisory Council built three solar batch type water heaters at three different workshops around Dumas.

The three units cost $750. The funding was provided by the Arkansas Energy Office and the Dumas Chamber of Commerce. Two of the units built were similar to the Harrison CETA Solar Energy Workshop Design, but the third one was different.

It was a "Sun Mummy" design, originally conceived by Albert Skiles, a Fayetteville architect, in conjunction with Community Energy Futures, Inc., of Little Rock.

This two-tank design is based on the use of widely-available, tempered glass panels that measure 34 × 76 inches.

Building the "Sun Mummy" is discussed in the *Solar Retrofit Guide*, available through the Energy Hotline: 1-800-482-1122. For plans, you also may contact:

Albert Skiles
Solar Design Architects
230 West Center Street
Fayetteville, Arkansas 72701
Phone: 442-3849

John Crone Put His Solar Collector on Wheels at Winslow; It Travels with the Seasons

John Crone
University Of Arkansas
School of Architecture
Fayetteville, Arkansas 72701
Telephone: 575-4705
Government Grant: $250
Crone's Project Was a Freestanding — and Mobile — Solar Air-heater for His Farmhouse.

BACKGROUND

John Crone, an assistant professor of landscape architecture at the University of Arkansas in Fayetteville, lives in a turn-of-the-century farmhouse that he is making energy-efficient. He is using solar energy for heat.

One of his solar retrofits is unusual — it's a collector on wheels!

The wheels permit Crone to move the air heater when not needed in the summer so it can be rolled out of the way, and out of the summer sun.

While the 50-degree tilt angle maximizes heat collected in winter, the summer sun can degrade the collector. Every April, Crone hitches the solar collector to his vehicle's trailer hitch and moves it. In October, he sets it up again.

BUILDING DESCRIPTION AND ENERGY CONCERNS

The south side of the house has been retrofitted with a solar greenhouse. With all that glass on the south, there was little need — or room — for another collector.

However, the north end of the house typically was about 12 degrees cooler than the south end. To remedy that problem, the collector is placed at the east end of the house and ducts route its heat to the north end of the house.

SOLAR RETROFIT DESCRIPTION

The collector is single-glazed with Filon and measures 4 × 16 feet. It employs a corrugated metal absorber. The air path is behind the absorber plate. The back of the unit is insulated with half an inch of Technifoam foil-faced rigid-board insulation.

Six-inch ducts, insulated with fiberglass and wrapped with plastic, pipe air between the collector and house. Standard six-inch duct boots were used at the collector inlet and outlet.

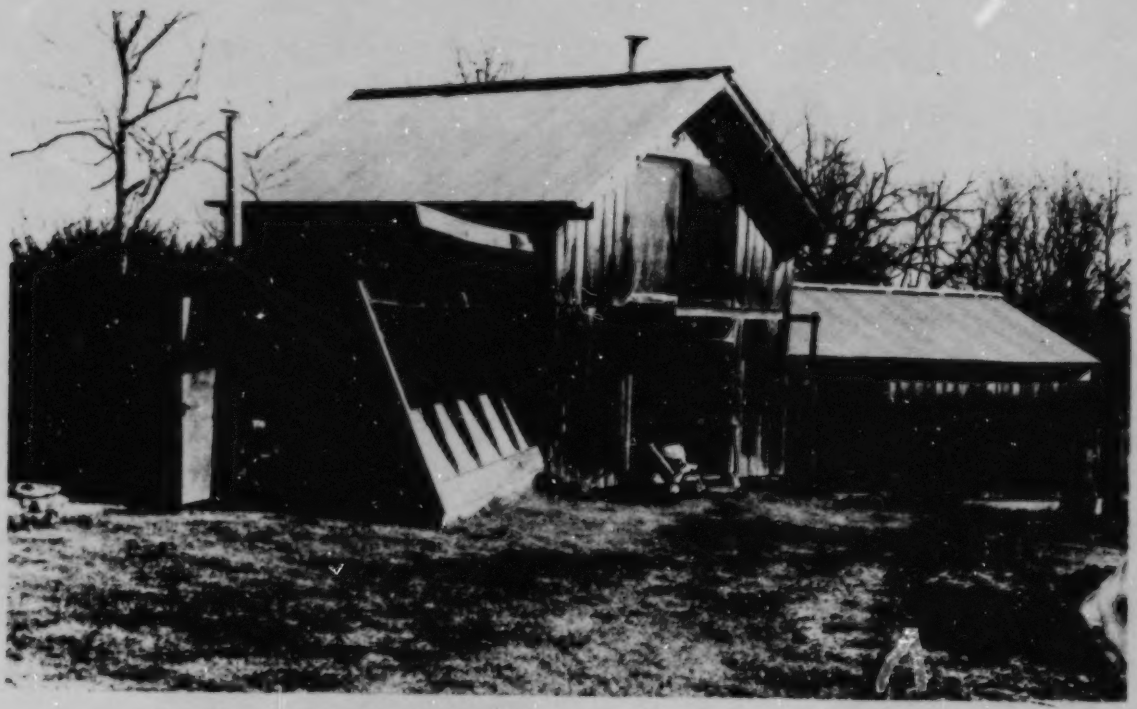
A 100 cubic-feet-per-minute, thermostatically-controlled fan mounted inside a window pulls air through the collector.

PERFORMANCE AND OPERATING HISTORY

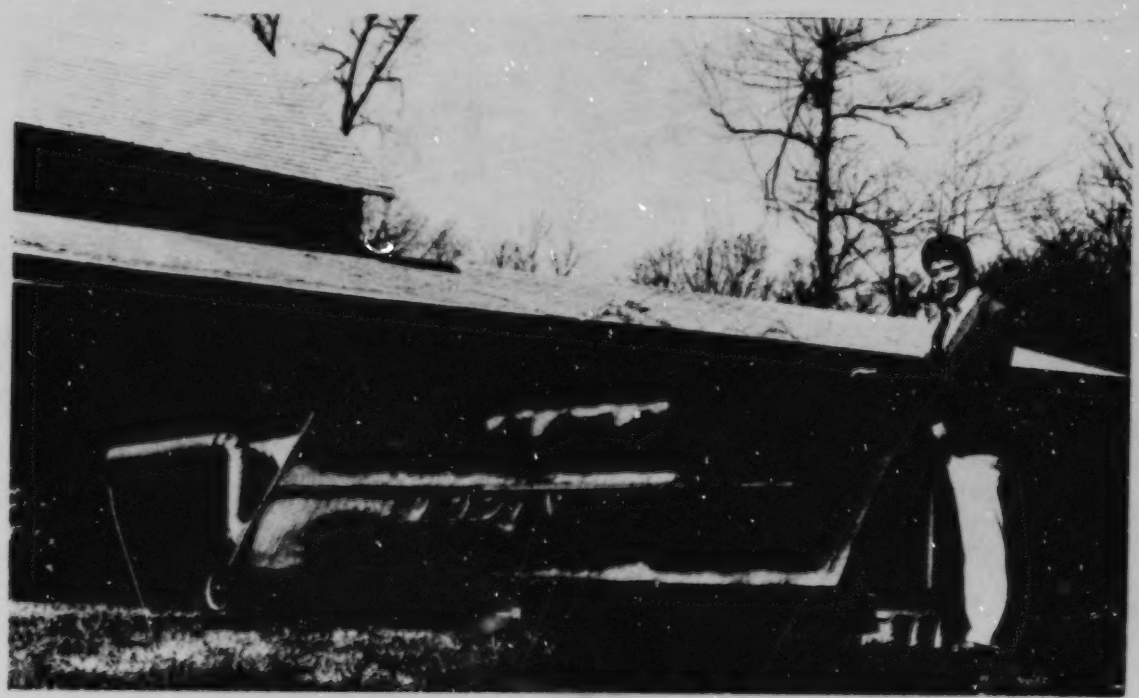
During the winter of 1980-1981, Crone performed a number of tests on the system. The 100 cubic-feet-per-minute fan was judged to be the most appropriate size, in an August, 1981 report. With no fan at all, thermosiphon action will deliver some air, but according to Crone, "the adjacent room never heated adequately" in this mode.

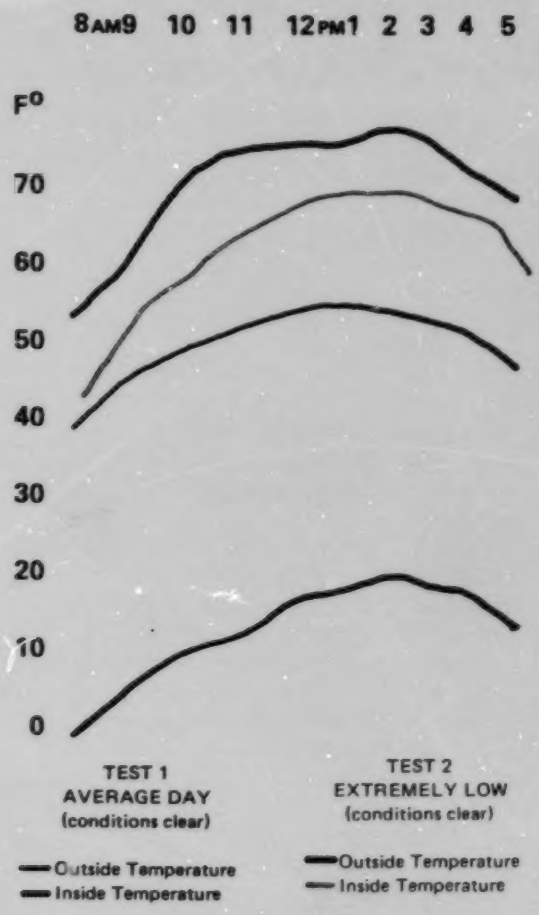
Too large a fan results in semi-heated air and drafts. Positioning the fan in the hot-air-outlet stream presents problems; the fan often reaches 180 degrees, which tends to dry out the motor bearings.

Crone said, "It may prove advisable to place the unit in the cold-air intake and push air



The solar greenhouse heats the south end of this Winslow farmhouse (above) while a mobile solar collector (below) heats the north end.





The mobile collector proved surprisingly efficient, according to records kept by Crone in the course of his experiment.

through the collector."

A trial was made using double-glazing with an inner layer of clear vinyl. Problems with sagging and condensation resulted, so this was not pursued.

Crone suggested placing the vinyl over blackened two-inch chicken wire as one way to overcome problems of sagging.

The heated north room and outside temperatures were monitored on both average-temperature and cold, windy winter days.

The records show that extremely cold outside temperatures and wind do not result in much loss of collector efficiency.

Crone said, "Operation on cloudy days was surprisingly good. The thermostat in the collector simply turned the unit on and off automatically to adjust for cloud cover." The best thermostat setting proved to be 90 degrees.

Crone spends approximately one hour in spring and fall taking down and setting up the collector.

COSTS AND BENEFITS

The total collector cost was $200. Supplemental heat for the home, which replaced other fuels, and the subsequent savings, are the benefits.

Almost 20 percent savings in heating costs might be expected for a typical residence.

The Office of Human Concern at Rogers Taught Solar Air-heater Construction

Office of Human Concern
Instructor: Joel Davidson
P. O. Box 756
Rogers, Arkansas 72756
Telephone: 636-7301
Government Grant: Ozarks Regional Commission
Air-heater Workshops Were Held Throughout Arkansas in 1981 .

BACKGROUND

Between 1979 and 1981, the Office of Human Concern's Solar Projects crew — Joel Davidson, Steve Meshca, and Robert Knapp — conducted dozens of solar air-heater workshops throughout Arkansas. Many of these were held at community colleges and vocational-technical schools.

The workshops, which were supported by the Winthrop Rockefeller Foundation and the Ozarks Regional Commission, typically were two-day affairs. They were free of charge. Usually from 10 to 40 people participated, and five solar collectors were built.

After the workshop, the collectors were given to local residents by the school where the workshop was held. Most of these collectors went to low-income, elderly residents whose homes were already adequately weatherized and insulated.

In some cases, the recipients had participated in the workshop and built the collector they eventually took home.

The low-cost solar air-heater itself can be built with simple carpentry tools and skills, using locally-available materials. Collector operation is completely automatic.

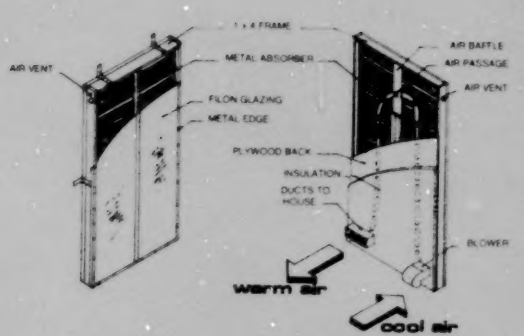
MATERIALS AND PROCEDURE

Plywood and 1 × 4s are used to construct the collector box. Latex caulk is used to seal the edges. The center 1 × 4, which serves to support the glazing, is notched and a metal ledger is attached. This ¾ inch × 24 inch notch forms the air baffle where the moving air changes direction as it moves from one chamber to the next. The edges of each chamber are then lined with 1 × 2s to support the absorber plate — something the metal ledger does in the notch area.

Two 2 × 8 sheets of galvanized steel or aluminum corrugated roofing are used for the absorber. Eight pieces, measuring 26 inches × one foot, 10⅞ inches, are needed.

These absorber pieces are fastened to the 1 × 2 lip with ¾-inch roofing nails every three inches. The corrugations will be perpendicular to the air flow. After cleaning off any grease or oil, the metal is etched with vinegar or muriatic acid so paint will adhere. It is then painted with a moderate-temperature flat-black paint.

After the fiber acrylic glazing is installed and the rest of the collector box is painted with exterior house paint, the unit is ready for installation.



Air circulates through the solar air heater.

PERFORMANCE AND OPERATING HISTORY

The monitoring of solar air-heater performance at several Northwest Arkansas locations was conducted by the Office of Human Concern in the winter of 1979 - 1980. Viewed statistically, this period was representative of average Ozark winters.

Ten homes with solar air-heaters were selected as representative of the homes occupied by low-income elderly people in Benton, Carroll and Madison Counties.

Seven homes were heated with natural gas and three homes were heated with propane. Fuel consumption for the past three years was obtained from fuel suppliers — Arkansas Western Gas Company and Sungas Company.

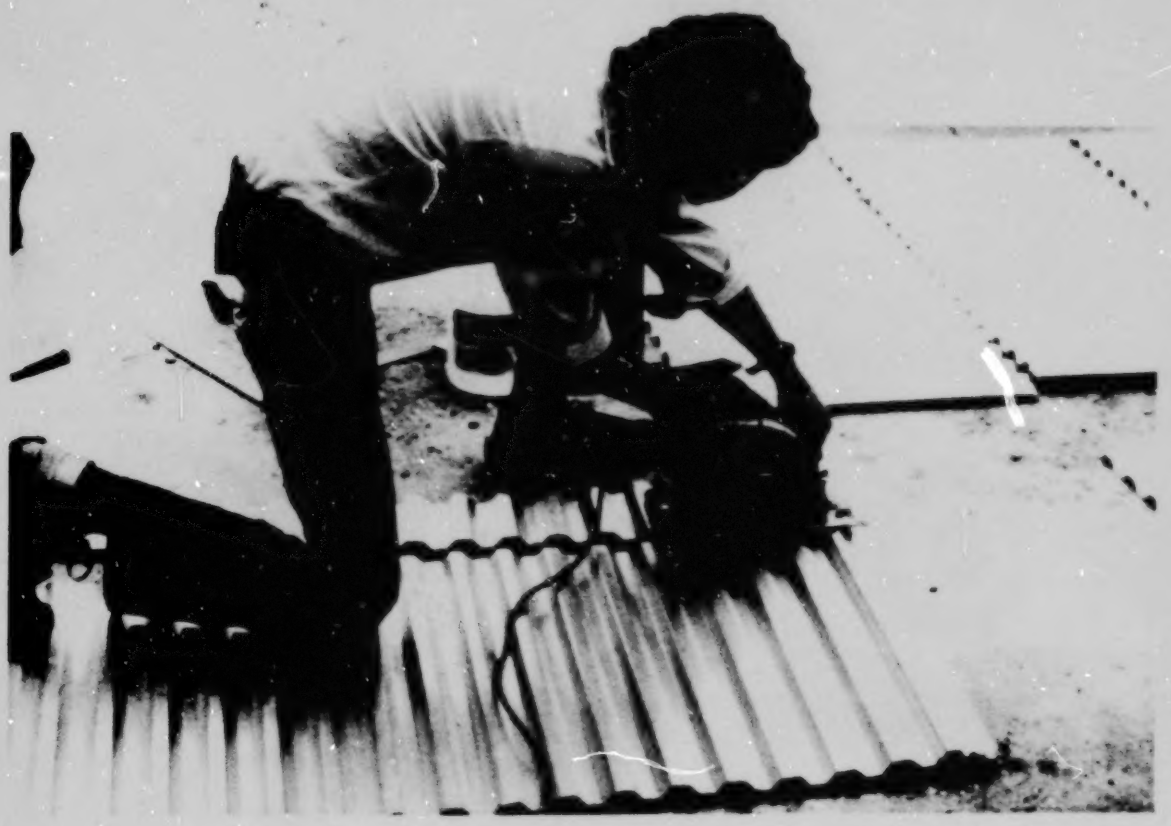
The air heaters were then being used with a smaller blower than is now recommended.

Almost all homeowners reported that the regular heating furnace either automatically shut off (or was turned off or down) while the collector was operating.

In the test homes, actual dollar savings ranged from 6.3 to 13.44 percent, with about 10 percent average savings.

In addition, special monitoring was done at Rogers and Eureka Springs from October 10, 1979 to February 26, 1980. According to Joel Davidson, here are some of the results:

"A typical instantaneous test with cool air entering at 70 degrees shows 2,736 Btu's per hour of usable heat delivered from the solar air-heater. This figure is based on the use of the first series of blowers used, which delivered 63 cubic feet per minute. The new blowers deliver 113 cubic feet per minute and produce 4,908 Btu's per hour under the same condi-



Solar collector takes shape under the hands of workshop student.

tions."

"During a six-hour operation," Davidson continued, "the new solar air-heaters typically deliver approximately 30,000 Btu's. During the measured test period, (October 10, 1979 to February 26, 1980) solar air-heaters were in operation 80 days, producing approximately 1.25 million Btu's using the older blower."

Davidson said, "This figure would be double if the new blower were in operation. All units are now being installed with the new blower."

"In addition," Davidson continued, "Tests have indicated that the use of an adjustable thermostat 'fine-tuned' for the particular house will add at least another two hours of operation and deliver an additional minimum .75 million Btu's.

Electrical consumption at the Eureka Springs location was 27 kilowatt hours and at the Rogers location 29 kilowatt hours. The blower consumes approximately .75 amperes or approximately 80 watts.

The solar air-heaters operate on sunny days from 9:30 a.m. until 3:30 p.m., on the average, for a total average of six hours' worth of electricity during the test period of five months."

Air heater maintenance requires the owner to keep the air registers and blower free of dust and to make sure furniture does not block air flow.

Vertical rather than tilted positioning on a south wall is important in reducing the degradation of the collector by the summer sun. The Temp Vent automatically vents very hot air buildup in the summer and that also helps the unit's longevity.

Of course, the collector may need a little paint after a few years operation. Doug Rye, architect for the federal Farmer's Home Administration in Little Rock, estimates the units should last 10 years without major repairs, if some maintenance is done.

COSTS AND BENEFITS

The 4 × 8-foot solar air-heater cost about $150 in 1981. It requires about 24 hours of labor to build and install.

A major benefit would be the 10 percent savings on fuel costs. And, according to Davidson, "It is expected that this figure will increase with the use of the larger blower delivering more cubic feet per minute and the adjustable thermostat increasing the total hours of operation. In addition, as fuel costs continue to rise, savings resulting from the solar air heater will increase."

Davidson said that the payback — using the smaller blower — is eight years for natural-gas-heated homes and three years for propane-heated homes.

Paybacks are based on natural gas at $2.25 per thousand cubic feet and propane at 60 cents per gallon (1980 prices).

FOLLOWUP INFORMATION

Complete instructions for building this air heater are in the publication *Solar Air Heater Manual* available from the Office of Human Concern. The cost is $5.

The model currently recommended by the Arkansas Energy Office is a state-of-the-art aluminum-framed collector with low-iron glass and semi-selective absorbor coating. Plans are available from the Arkansas Energy Office.

2 Active Solar Energy

Arkansas Solar Experiments Showed It's Best to Get the Most Btu's for the Dollar

Compared to the low-technology retrofits of Chapter 1, the active systems discussed here are more complex and will require more maintenance. As a group, they may not be as cost-effective as the simpler retrofits, although there will be individual exceptions.

SOLAR WATER HEATING

There are four approaches to acquiring a solar hot-water system.

First, you can use commercially-built collectors and system components. Choosing among competing collectors and systems is part of this approach, whether you install the system or employ a local solar mechanic, perhaps someone found in the Yellow Pages listing of solar energy equipment and system dealers.

Solar collectors are tested according to standard procedures and the results are available to consumers.

In shopping around, getting the most Btu's per dollar invested is the best approach.

However, many will choose to have local solar contractors or distributors furnish, install and maintain the system. This can save much time and trouble, but it is the most expensive route.

You will also be limited to the systems the business is in the habit of installing. This may not be a disadvantage, however, because if the company has much experience, sales personnel can tell you what to expect.

Second, you can assemble the collectors from commercially-made absorber plates. This is far simpler than building the entire collector.

In this approach, you buy the part that is most difficult to build, and furnish a glazed, insulated box to house it. The rest of the system comes from off-the-shelf components, although perhaps one or two items may be fabricated. Installation and maintenance can be done by you or with help from a local solar mechanic.

Third is the most difficult and time-consuming route; potentially, it is even cheaper. You can build the collectors completely from scratch, including absorber plate.

Unless you are building many collectors and are particularly skilled, this option offers no real cost savings over buying an absorber plate.

Bart Hudspeth of Harrison concurs with this. He said that after building four collectors and spending untold wasted hours learning to solder the absorber plate, his fifth and final collector took about one day's work.

Solder and the other materials are no bargain in small quantities and it will be difficult to approach the efficiency of the commercial absorber plate with a homemade job.

Finally, you may build a solar batch heater as described in Chapter 1.

While three approaches described here employ a collector fluid, which circulates between collector and storage, the batch water-heater is non-circulating. Collection and storage are integrated.

Projects described in this chapter include thermosiphon, draindown and closed-loop heat exchange systems, using a variety of collector fluids.

If a circulating fluid other than silicone is employed, careful attention to the manufacturer's recommendations for periodic change-out is a must.

Most of the systems employ freeze protection. One project described, the absorber built in the Community Energy Futures workshop, needs no freeze protection; but it does need summer "meltdown" protection.

Installation is especially critical for draindown systems, to insure freeze protection, and for thermosiphon systems, to insure proper circulation.

The Arkansas Energy Office no longer advises individuals to construct homemade absorber-plate solar collectors, as described in this book. The Arkansas Solar and Hydronic Heating Code, which went into effect in the summer of

PROJECT COMPARISON OF VARIOUS SYSTEMS

Application	System	Collector Fluid	Project
Domestic Hot Water	Closed Loop Heat Exchange	Silicone	Paragould Bath House
Domestic Hot Water/ Space Heat	Closed Loop Heat Exchange	Hydrocarbon Oil	Waechter
Pool Heating	Closed Loop Heat Exchange	Glycol	Hudspeth
Domestic Hot Water	Draindown System	Water	Museum; Summercorn
Domestic Hot Water	Thermosiphon System	Water	Meadowcreek

1984, requires that all collectors used in water heating systems be certified by the Solar Rating and Certification Corporation (SRCC) or approved as equivalent by the Arkansas Department of Health. In addition, the new Code has other provisions with which solar hot water system installers need to be acquainted. Contact the Arkansas Energy Office for more information.

SOLAR SPACE HEATING

Systems which supply space heat along with hot water clearly require more collector area. Thus, the Waechter system employs 432 square feet of collector instead of the 50 to 100 square feet typically required for domestic hot water. If no hot water, but only winter heating is desired, the solar air systems with storage may be more cost effective than liquid-type solar systems. The Scroggins office building described in Chapter 3 provides an example.

Clearly the payback period for a space heating investment is not as short as that for a solar domestic hot water system.

SOLAR AGRICULTURAL APPLICATIONS

This chapter includes accounts of several projects of active solar applications in the agricultural sector. Among these are broiler house heating, commercial greenhouse heating and lumber drying.

Waechter Family at Omaha Gets More Than Half its Heat and Hot Water from the Sun

Jim and Geri Waechter
Route 1, Box 84A
Omaha, Arkansas 72662
Phone: 426-5134
Project Grant: None

Active Solar Domestic Hot-water and Space-heating System Serves the Family of a Former Machinist.

BACKGROUND

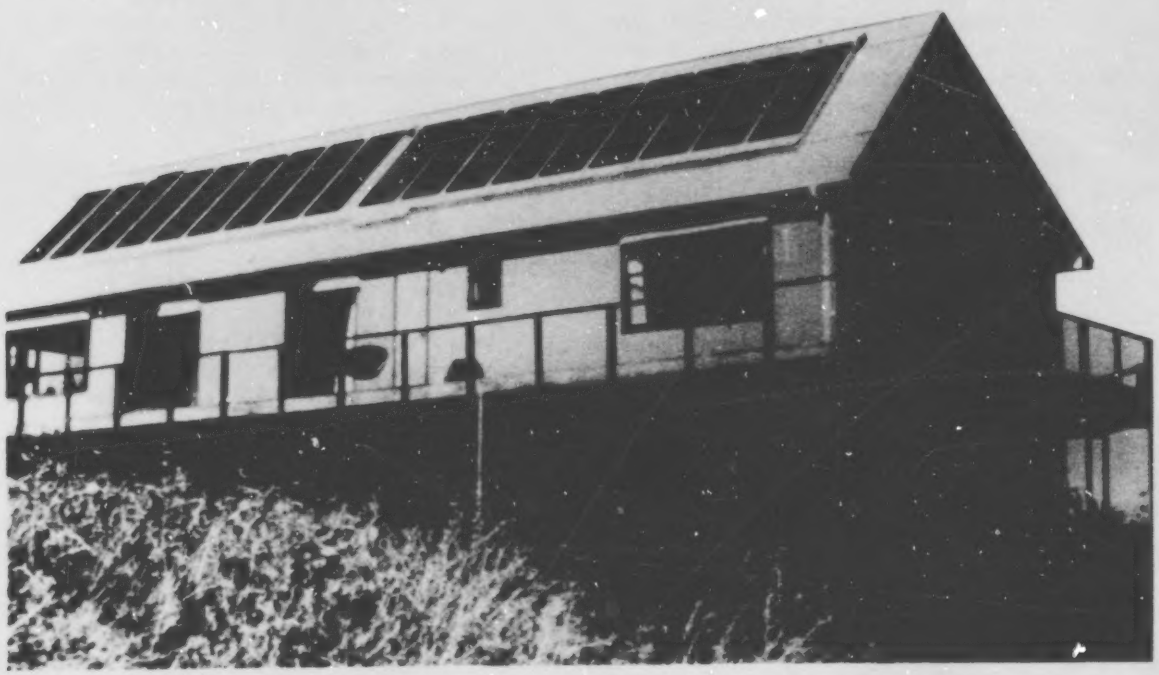
Jim and Geri Waechter came to Arkansas in 1978 from the state of Washington, and built a passive solar house. Waechter, who served in the Navy 20 years as a chief warrant machinist, was inspired by Bruce Anderson's book *The Solar Home Book*.

By June 1979, he had installed a roof-top active solar system to provide both space heating and hot water.

BUILDING DESCRIPTION AND ENERGY CONCERNS

The 1,400-square-foot home is well-insulated and uses electricity for all appliances. The home has a basement and 150 square feet of windows on the south wall.

Shades and drapes are used to cut night-time heat loss out these windows in winter, and an exterior vinyl roll-down shade cloth cuts out



Array of solar panels creates interesting pattern on the roof of the Waechter home.

the summer sun. There is no overhang.

COLLECTOR

The Waechters use 432 square feet of active collector, provided by 18 panels. Each panel measures 3 × 8 feet. They are flush-mounted on the roof at a 45-degree, south-facing angle. The collectors were made by Weathermade Systems, Inc. of Springfield, Missouri and employ an Olin Solar-Bond copper absorber plate.

STORAGE

A 1,000-gallon, well-insulated, ¼-inch steel tank in the basement provides thermal storage for the space-heating system. A heat exchanger, which is just an Olin absorber plate like those used in the collectors, is immersed inside the tank.

CIRCULATION

A non-toxic, hydrocarbon-based synthetic oil serves as the working fluid in this closed-loop system. The 18-panel collector array has two sections of nine collectors, and each has a 1/12 horsepower pump.

CONTROL

A Delta-T differential controller governs pump operation. A manually-operated switch controls whether heat is dumped into the hot-water or space-heat tanks.

DISTRIBUTION

Water from the space-heat tank gives up its heat to air through a heat exchanger inside an air-handling unit. A blower, part of the same unit, sends the hot air through ductwork to the rest of the house.

AUXILIARY ENERGY SYSTEM

Electric baseboard heaters for space heating and an electric heating element inside the hot water tank are employed.

DOMESTIC HOT WATER

An 80-gallon tank, with an internal copper coil heat exchanger, serves as the hot-water tank.

PERFORMANCE AND OPERATING HISTORY

During the middle of 1980, the system supplied all the house hot water for 128 straight days — a period during which backup was not needed.

Monitoring during the first year of operation logged 2,032 hours of pump operation. This represents an average of 5½ hours daily. One indication of the system's space-heating contribution comes from utility bills before and after installation of the active system.

For February and March 1979, an average of 1,755 kilowatt hours per month was used. February and March 1980 show an average of 887 kilowatt hours per month, a reduction of almost 50 percent.

Waechter had some problems with leaks at pipe joints. He attributed the leaks to the low viscosity of the synthetic-oil fluid.

There is no cold-water mixing valve and the Waechters have had to warn guests about possible 180-degree water temperatures and the need to turn on the cold water first to avoid severe burns.

COSTS AND BENEFITS

The total active system cost was $9,200, including $7,000 for the collectors and $500 for the space-heating 1,000-gallon tank.

Active solar contribution to the combined hot-water and space-heat load is believed to be 60 to 70 percent, as of a June, 1981 visit. The Waechters expect the system to pay for itself in 10 to 12 years.

Slide Program 1, *A Northwest Arkansas Active Solar Home*, available at the North Arkansas Community College Library at Harrison, documents the project.

Paragould City Officials Heat Water with Solar Energy at Reynolds Park Bathhouse

Reynolds Park Bathhouse
Paragould Parks and Recreation Department
P.O. Box 413
Paragould, Arkansas 72450
Telephone: 239-5338
Government Grant: $1,500
A Trouble-free System Uses Solar Energy to Provide Hot Water for Bathhouse at Swimming Pool.

BACKGROUND

The swimming pool and adjacent bathhouse at Reynolds Park at Paragould only operate during the summer, so the system sits unused the rest of the year. In order to overcome potential stagnation problems and minimize maintenance, silicone was used as the heat-transfer fluid in the collectors. Silicone will not freeze or boil at anywhere near the temperature encountered in a solar collector. It is also extremely stable, never needs replacement, and is now guaranteed for 20 years. It is ideal for installations where maintenance needs to be kept to a minimum.

It would not be wise to let a solar collector filled with a glycol-type antifreeze sit stagnant for months. The heat build-up in the collector, which is normally removed by circulating the fluid, can hasten the breakdown of the glycol into corrosive organic acids. Unless the fluid is changed periodically, (normally every two to three years) these acids may damage the collector absorber plate.

Also, problems with glycol "boiling dry" have been reported in stagnated collectors.

Silicone fluid has special properties and flow characteristics that require a highly-specialized heat exchanger to remove the heat efficiently and transfer it to the potable water. The industry now recognizes that a simple coil of tubing inside the storage tank does not remove enough of the heat. Instead, the heat stays in the silicone fluid and goes right back up to the collectors.

This system has a heat exchanger device located outside the storage tank. The hot collector fluid runs one direction through a large copper shell while the potable water is piped the other direction through the coil inside the shell. This is a very efficient way to transfer the heat from one fluid to another.

Workers lift solar collector to roof of bathhouse during installation of solar system at Reynolds Park.

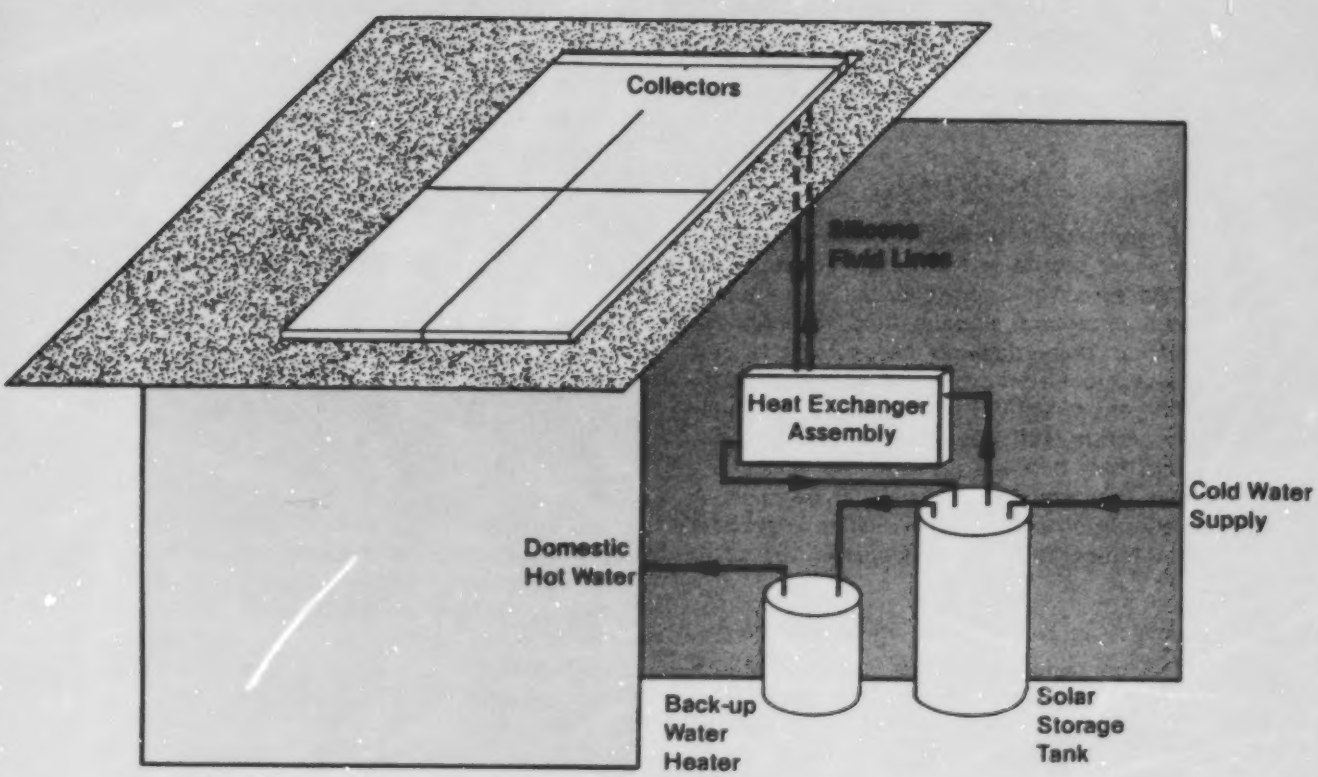


Diagram illustrates flow of water through the Suncatcher solar collector system in use at Reynolds Park Bathhouse.

The chief drawback to using silicone for the collector fluid is its cost — approximately $35 per gallon. The fact that, at most, a few gallons are required and that it never needs replacing, makes this added initial expense justifiable.

BUILDING DESCRIPTION AND ENERGY CONCERNS

Reynolds Park, site of a large public swimming pool, is used by 7,500 people each month during the summer. After Labor Day, the circulating pump for the solar collector on the bath house roof is unplugged and the solar system sits idle until next summer, as the facility is closed.

COLLECTOR

City officials used one Suncatcher SH21, manufactured by Solar Unlimited, Inc., which is a 3 × 13-foot, double-high collector with Sunadex-tempered glass glazing.

STORAGE

An 82-gallon, glass-lined tank insulated with fiberglass from the A.O. Smith Company was used. It is 62 inches high and 24 inches in diameter.

CIRCULATION

To move fluids, a Grundfos 1/12-horsepower, cast-iron housing "can" pump providing a two-gallon-per-minute flowrate was used.

Silicone systems need approximately twice the flowrate of glycol systems. This increases operating costs slightly. Paragould officials used the heat-transfer silicone fluid known as

Sytherm 444, manufactured by Dow Corning. Four gallons were needed.

The external counterflow heat exchanger, also made by Solar Unlimited, Inc., is of double-wall construction.

CONTROL

When the collector is 20 degrees hotter than the water stored in the 82-gallon tank, the system's electronic controller activates a pump, which circulates silicone fluid through the collector, down through the heat exchanger, and back to the collector — all in a closed loop.

The entire system will run until the water temperature and collector temperature are within three degrees of each other or until the water temperature reaches 160 degrees. A safety cut-off of the entire system is set at a water temperature of 180 degrees.

DISTRIBUTION

The controller simultaneously activates a stainless-steel pump, which circulates domestic water out of the 82-gallon storage tank, up through the heat exchanger and back into storage.

Each time hot water is used, solar preheated water automatically replenishes the existing domestic hot-water heater supply, and at the same time, cool city water is drawn into the solar pre-heat tank.

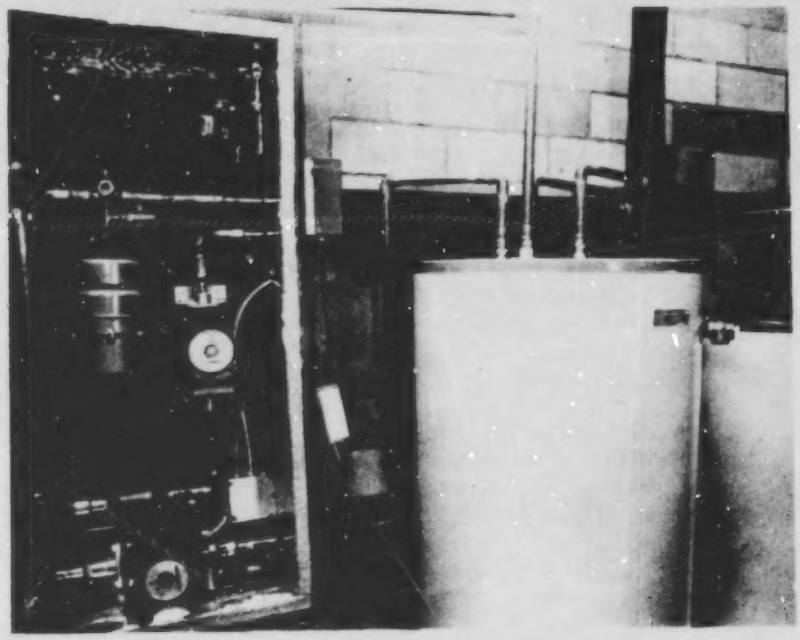
AUXILIARY ENERGY SYSTEM

The existing domestic water heater is a 40-gallon electric unit.

PERFORMANCE AND OPERATING HISTORY

The installation has operated since May, 1980 with no problems whatsoever. The system supplies virtually all of the bathhouse's hot water; during the first season of operation, no backup heat was needed.

The hot-water demand, highest on warm sunny days, is nicely in tune with system



Heat exchanger assembly (in frame at left) is notable in the Paragould solar system for extracting heat from silicone circulating fluid.

production. There are more swimmers at the pool on hot, sunny days.

COSTS AND BENEFITS

Chief expenditures have been:

Collector	$ 495
Heat Exchanger	580
82-gallon tank	205
Silicone Fluid	100
Miscellaneous Plumbing and Hardware	210
Installation Costs	185
Other	65
TOTAL	$1,840

The payback period on a seasonal solar installation such as this one is not very good, although auxiliary energy for the bathhouse's hot water is no longer an expense.

This is because the solar hot-water system sits unused for almost three-quarters of the year, unlike a residential application.

The project's chief benefit has been the high visibility of the solar installation and its trouble-free, reliable service.

For more information, contact the firm that installed the system for the city:

Bob and Pat Lee
The Solar Shop of Paragould
Route 4, Box 211
Paragould, Arkansas 72450

Museum of Science and History at Little Rock Uses Solar Energy to Heat Water

Museum of Science and History
MacArthur Park
Little Rock, Arkansas 72201
Telephone: 376-4321
Government Grant: $8,000
Drainback Solar System Provides Space Heat and Hot Water to Museum at MacArthur Park.

BUILDING DESCRIPTION AND ENERGY CONCERNS

The system serves the museum's exhibit preparation room, a small building next to the museum itself. The roof-top collector site is somewhat shaded by a nearby building in late afternoon.

Six American Solar King SG-15 rack-mounted collectors provide a total of 134 square feet of collector.

The system uses a 220-gallon fiberglass tank, three feet in diameter and over seven feet tall. It is insulated with three inches of urethane and can withstand temperatures up to 325 degrees.

A 1/12 horsepower Grundfos pump circulates treated water through the collector.

A two-stage thermostat governs pump operation.

For the space heating, a 1/20 horsepower Grundfos circulating pump sends water to a heat exchanger in an air-handling unit. Heat is transferred to the air, where it is distributed to the building through ducts.

The auxiliary heating is electric.

A heat exchanger carrying potable water, located in the storage tank, transfers heat to a 20-gallon conventional electric domestic water-heating tank.

PERFORMANCE AND OPERATING HISTORY

The system was installed in the summer of 1980, and still is working today. Several problems have been overcome; most involved correcting errors in installation.

COST

The entire system, including a 1½-ton air-conditioning unit, cost $8,000 installed.

Solar collector converts sunlight to heating and heated water at the Museum of Science and History at MacArthur Park. The unit sits atop the building where exhibits are prepared.

Solar Energy Heats Swimming Pool at Holiday Inn at Harrison

Bart Hudspeth
Holiday Inn
902 West Sherman Street
Harrison, Arkansas 72601
Phone: 741-2391
Project Grant: None

Bart Hudspeth, Manager of the Holiday Inn, Designed and Built Solar Swimming-pool Heating System.

BACKGROUND

Bart Hudspeth, a Harrison businessman, refers to his designing, building, installing, and operating an active solar system as a great "educational adventure".

In 1979, Hudspeth set out to use solar energy to heat the indoor pool at the Holiday Inn in Harrison, where he is owner and general manager.

However, instead of having a solar contractor provide a "turnkey" system, he built or assembled nearly everything himself, from locally-available materials.

Hudspeth soldered copper absorber plates, built redwood boxes, and insulated, glazed, and constructed rack mountings for five solar collectors. He designed and built a heat exchanger for his closed-loop system, which is charged with antifreeze. He also created the rest of the plumbing hookup.

By early 1980, the system almost became operational. However, upon charging the system with five gallons of ethylene glycol and starting the pump, Hudspeth realized he had problems.

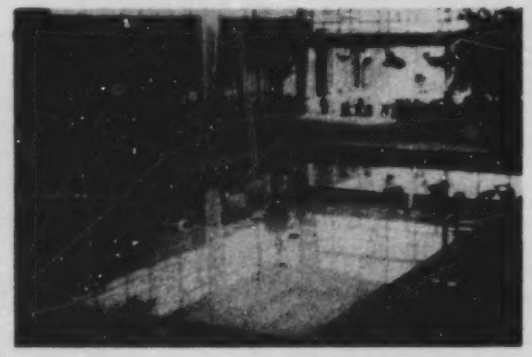
He could not get the 1/20 horsepower pump to circulate, for the pump had not been sized right. This problem was finally solved by using three of these 1/20-horsepower pumps hooked together piggyback.

Hudspeth also experienced trouble building the collector absorber plates. Despite these and other difficulties, however, the system has provided satisfactory operation.

Hudspeth said that he believed it has been worth all of his effort. Not only did he put together a commercial-building solar pool-heating system for less money than solar contractors charge for domestic hot-water systems, which would serve a lesser demand, but he also got a great "hands-on" solar education!

BUILDING DESCRIPTION AND ENERGY CONCERNS

The 800-square-foot pool is located inside an enclosure that is 80 × 100 feet. The roof, called the Solardome, is made of Kalwall glazing, 0.025 inches thick. Despite the name, the roof's function is to let massive amounts of light, not heat, into the facility.



This indoor pool gives pleasure to motel guests while its solar heating keeps costs under control.

The collectors are mounted on the south end of the roof and are relatively distant from the pump/heat exchanger room down below. That meant that longer-than-usual piping runs were needed.

There is a 26-foot difference in elevation between the collectors and the heat exchanger, and 140 feet in the total circuit of pipe.

Because this installation is on a commercial building, liability considerations necessitated a rugged, 1½-inch welded-steel angle collector rack mounting. This added almost $500 to the project costs.

Swimming goes on year round in the motel pool. The temperature is kept at 70 to 85 degrees depending on time of year. The goal of any solar pool-heating installation is to lengthen the season during which no costly backup heat is needed.

COLLECTOR

There are 144 square feet of single-glazed, owner-built collector, consisting of five units plumbed together in series. The glazing is 0.025-inch premium Kalwall.

Four of these are 3 × 8 feet in size, and one is 6 × 8. The collectors have a serpentine ½-inch copper tubing grid, soldered to 16-gauge sheet copper. The collector boxes are built of 2 × 6-foot redwood insulated with Thermax.

A hinged reflector, also made of Thermax — foil-faced, rigid-board insulation — doubles as a protective cover during time when the system is inoperative — including mid-summer, when no pool heating is needed.

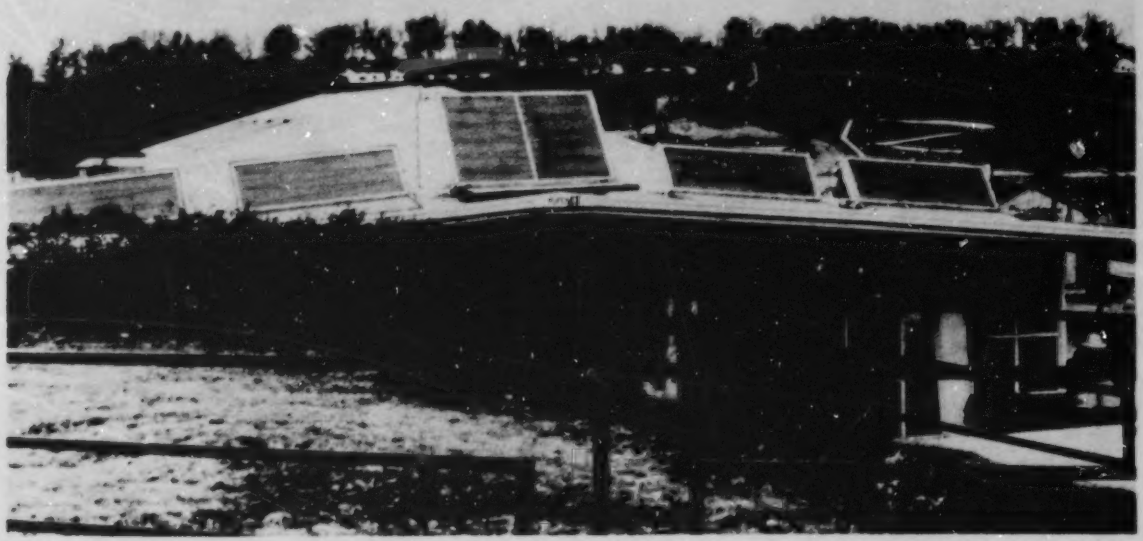
Collector tilt angle is a south-facing 41 degrees. The latitude plus 5 degrees slightly favors winter operation.

STORAGE

The 35,000-gallon swimming pool itself proides heat storage; there is no distribution system needed between storage and the point of end use.

CIRCULATION

Three 1/20-horsepower Grundfos pumps circulate ethylene glycol through the closed system. A heat exchanger, located inside a small boiler tank, transfers heat from the glycol to the pool water. The exchanger consists of 110 feet of ½-inch s[illegible] copper tubing arranged in two coils. The existing pool filtration pump circulates water between pool and heat exchanger.



Solar collectors adorn the roof of Holiday Inn and contribute to cost-efficient operation of the business.

CONTROL

A furnace fan limit switch mounted inside one of the collectors turns the pump on at 90 degrees and off at 80 degrees. This provides low-cost control, although it is not as efficient as a differential temperature controller.

AUXILIARY ENERGY SYSTEM

A 225,000-Btu-per-hour, natural-gas pool heater supplies extra heat.

PERFORMANCE AND OPERATING HISTORY

The solar installation supplies the pool's heat for three-quarters of the year, according to Hudspeth, in a September, 1983 interview. Temperatures of 110 to 120 degrees typically are delivered. A peak of 155 degrees has been recorded.

These are the most significant problems:

- Half-inch CPVC (hot-line plastic pipe) initially used for the lengthy piping runs "melted" after one month of operation. The failure was most pronounced at copper-to-plastic pipe connections and at fittings. The plastic has since been replaced with copper pipe.
- The 20-gallon boiler tank, which housed the heat exchanger rusted through. Leaks had developed on the water side of the heat exchanger. This home-built unit will soon be replaced with a commercially-made, stainless-steel counterflow-type heat exchanger costing around $500.
- The piping used for the lengthy runs should have been ¾ of an inch in diameter instead of ½ inch. Using the smaller pipe resulted in greater frictional losses and additional pumping power; an extra pump was needed.
- In series hookups, such as this one, higher collector temperatures are achieved and that results in greater heat loss and lower efficiency. For that reason, parallel configurations are preferable.

COSTS AND BENEFITS

Hudspeth estimated that initially around $2,000 was spent on this system. An extra $500 was spent on the heavy-duty collector rack mounting, which many installations would not have needed.

While the exact solar contribution is unknown, Hudspeth said he believed that his collectors meet close to 40 percent of the annual pool heating load.

Bernard Kreul Built a Solar Pond to Heat His Greenhouse at Nashville to Cut Energy Costs

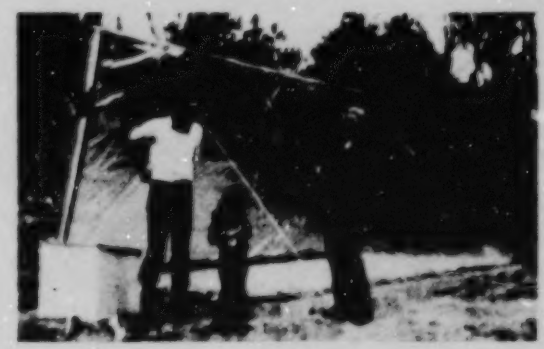
Bernard H. Kreul
Route 3, Box 129 AA
Nashville, Arkansas 71852
Telephone: 845-1823
Government Grant: $2,381
A Prototype "Solar Pond" Was Built to Heat an Existing 3,000-Square-Foot Greenhouse.

BACKGROUND

The system here was named a "solar pond" due to its configuration, but the structure should not be confused with the salt brine pond system of the same name.

The Kreul device consists of a 150-square-foot flat-plate horizontal collector augmented by a reflecting cover. Integral to the collector is a 3,000-gallon water storage pit.

The project's inspiration came from a desire to use stored solar heat to meet the night-time heating needs of a greenhouse of 3,000 square feet, which would permit Kreul to replace the natural-gas system. A technically-simple, low-cost system that could be built from locally-available materials was sought.



The Kreul family inspects the reflective cover of their heat-storage tank; below the cover is a 3,000-gallon underground storage tank.

BUILDING DESCRIPTION AND ENERGY CONCERNS

The small commercial greeenhouse supplies part of the produce needs of the local supermarket. Primarily tomatoes are grown; however, cucumbers, melons and a few other vegetables have also been grown.

Natural gas bills for the six-month heating season ran $500 to $600, with gas costing $2.72 per thousand cubic feet and a burner of 65 percent efficiency. These were costs before any solar system was in operation.

COLLECTOR

The collector is a horizontal 29-gauge corrugated aluminum absorber plate painted flat black. It measures 6 × 21 feet. It rests on ½-inch galvanized pipe on five-foot centers.

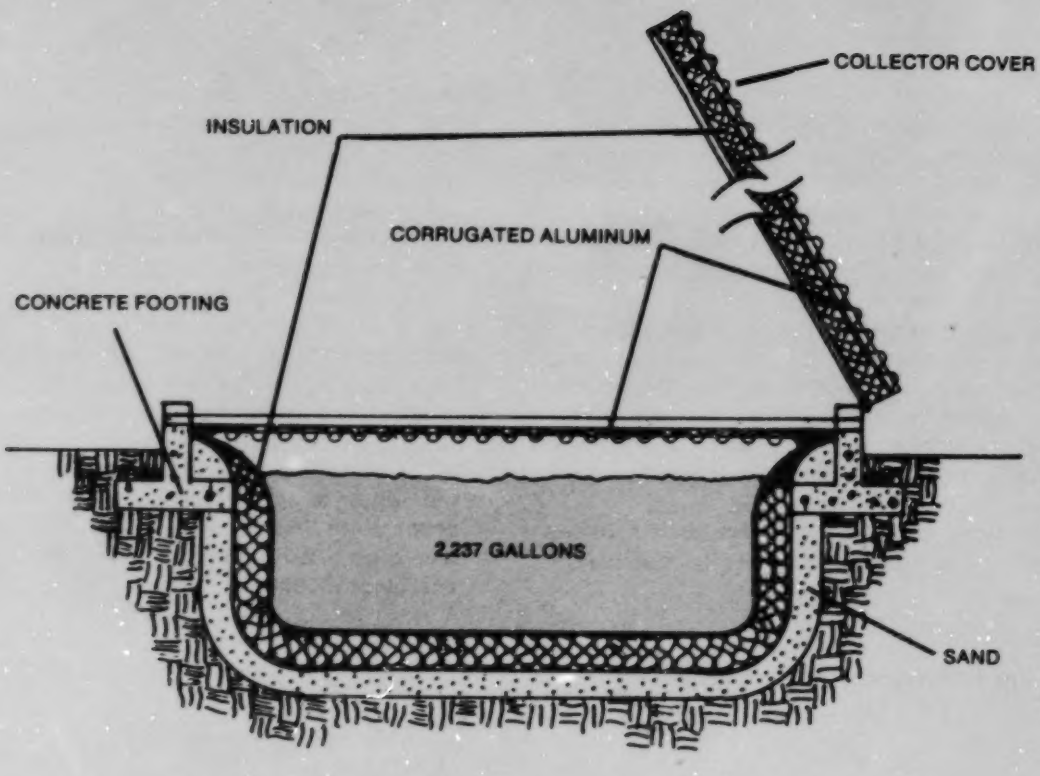
A sheet of Number 602 ultraviolet-resistant polyethylene glazing sits over the absorber. It measures 154 square feet.

Glazing installation was accomplished by laying the plastic on top of the absorber on a sunny day, allowing the heat to expand it before stapling it down to get a tighter fit.

An insulating/reflective cover provided 176 square feet of surface for reflection gain. The hinged cover, built of 2 × 4 frame construction filled with 3½ inches of fiberglass and covered with corrugated metal, employed an aluminum foil reflecting surface.

STORAGE

The 36-inch-deep pit contained 2,237 gallons of water. After a concrete perimeter footing



Cross Section of Solar Pond.

was poured, the pit was dug with a back hoe. It was filled with four inches of sand and four inches of insulation, and lined with plastic. The insulation is a rigid type that won't be compressed by the weight of the water.

CIRCULATION

A small sump pump and pipes circulate the water between the reservior and the absorber plate surface.

CONTROL

The sump pump circulates when a thermostat indicates the absorber is above 85 degrees. The Teel pump sends heat to the greenhouse whenever the greenhouse thermostat (set at 60 degrees) calls for heat and the pit thermostat (set at 65 degrees) shows heat is available. The reflector cover is manually opened or closed, with a hand winch, when morning sun is available or to prevent nighttime heat loss.

DISTRIBUTION

A Teel pump circulates hot water between the pit and two heat exchangers, which are used radiators. These are fitted onto the return air intake of the existing gas burners.

AUXILIARY ENERGY SYSTEM

A natural-gas burner feeds heat into convection tubing, which distributes the warm air down the length of the greenhouse.

PERFORMANCE AND OPERATING HISTORY

The projected annual net heat production is

28 million Btu's.

That represents a savings of $157.93 or at most 30 percent of the greenhouse heating bill. The collector was not large enough to provide the desired pit temperature.

However, tests (and subsequent calculation) show the collection and over-all system efficiencies to be rather high.

It appears that the thermal storage pit is "a very effective and economical means of storing large quantities of hot water," as Kreul put it.

However, he points out that "the requirement that the pit cover be manually opened and closed each day is, many times, inconvenient and confining."

In fact, this labor-intensive aspect of the system was the reason Kruel closed it down.

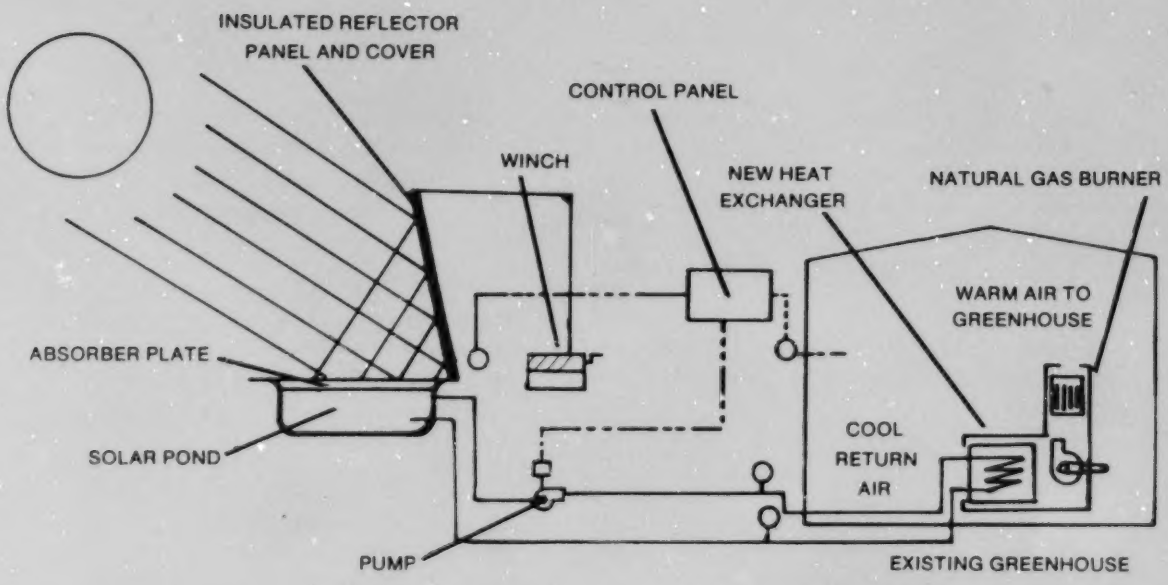
COSTS AND BENEFITS

The total project cost was $2,361, including design fees, transportation, etc. In a March 1983 report, Kreul concluded that, if scaled up, the cost per Btu could be significantly reduced.

For the system as built, simple payback calculations show a 13-year payback, based on replacing gas.

If the solar system instead replaces more costly elecric heat (assumed to cost 7.7 cents per kilowatt hour), less than a three-year payback is achieved.

According to Kreul, "A better system would consist of a separate and larger trickle collector of the same basic design, but inclined toward the winter sun, and a solar pit with a fixed cover. With these improvements, the system would be totally automatic, and much more energy productive, for little extra cost."



Schematic of Solar Heat-pond System.

Orr Brothers Installed Thermosiphon System at the Meadowcreek Project at Fox

David or Wilson Orr
Meadowcreek Project
Fox, Arkansas 72051
Telephone: 363-4500
Government Grant: $9,988
Solar Energy Features Were Included in Research Project That Created Self-sufficient Community.

BACKGROUND

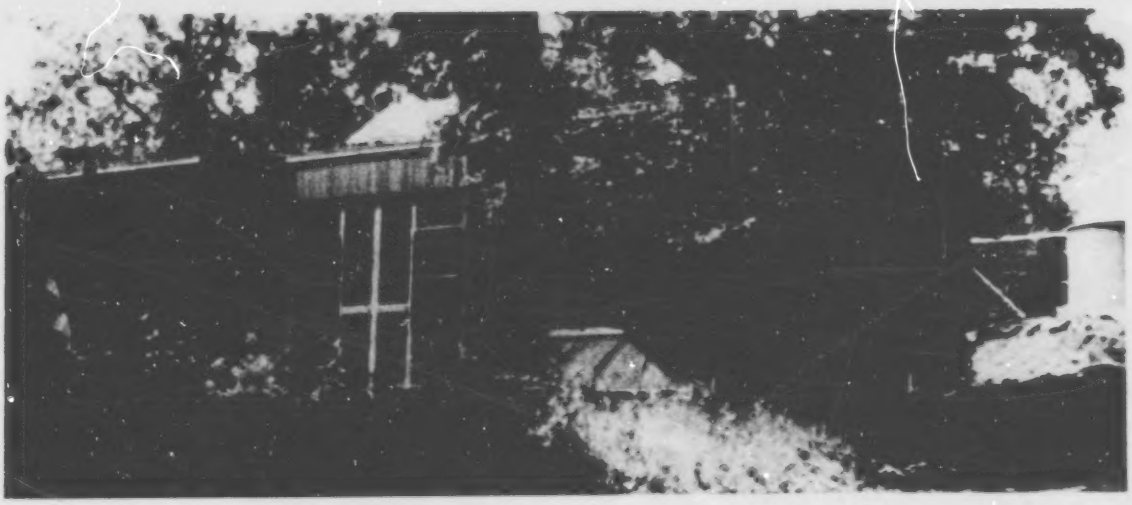
This is an educational complex for research in applied ecology and appropriate technology. The focus is on the thermosiphon solar hot water system on the project office building.

The project was established in 1979. Supporters described Meadowcreek's goals in a recent newsletter:

"Educational and research activities will be integrated with the physical elements of the Project, which include: (1) a 200-acre organically-operated farm with orchards, livestock ponds, greenhouses, field crops, intensive gardens, and processing center; (2) a micro-industrial area with a sawmill, wood products shop, solar wood-drying kilns, mechanical shop, blacksmith shop and metal foundry; (3) renewable energy systems producing mechanical power, electricity, and liquid fuels from microhydro, biomass, wind, photovoltaics, and direct solar; (4) a community of 50-60 permanent residents, co-op and recreation facilities; and (5) natural areas for both recreation and research. Each of the components of the Project — the farm, workshops, fields, forests, and structures — will also serve as classrooms, textbooks, and laboratories for educational activities."

Much of the above is already in place or under construction.

Recently completed were two units of the Educational Center. These are passive-solar, earth-bermed structures. One is 4,000 square



The office building at the Meadowcreek complex features a thermosiphon water-heating system.

feet and the other has 5,000 square feet. Both structures are designed to recycle organic wastes.

Hot water is provided by two active solar draindown systems, each with 300 square feet of collector surface.

Other structures include a 2,000-square-foot staff building with attached solar greenhouse, a 15,000-square-foot passive solar/earth-sheltered Educational Center (under construction), an office building and a sawmill/woodshop facility.

The wood-working shop is interesting because a steam-powered engine provides the mechanical power that runs the sawmill and other woodshop machines. The locomotive-type, fire tube boiler, steam engine is fueled by waste wood slabs from the sawmill.

In July 1982, the sawmill milled 102 oak timbers for Amory and Hunter Lovins' Rocky Mountain Institute at Snowmass, Colorado. Lovins and his wife are world-famous for their many books dealing with renewable energy and the "soft energy path."

The largest of the beams was 18 × 16 inches and ranged in length up to 22 feet. The entire load, weighing 35 tons, required two semi-trailers.

BUILDING DESCRIPTION AND ENERGY CONCERNS

The 1,500-square-foot office building is the oldest of the Meadowcreek Project's structures. It has a passive solar design, and employs a cistern, rain-water collection system, recycling composting toilet, 140 watts of photovoltaics charging a 12-volt battery bank, and thermosiphon solar hot-water system.

FOCUS

In 1979, interior, vertical south-wall-mounted solar collectors were installed below a 66-gallon storage tank to compose a thermosiphon hot-water system. The system never circulated properly as a result of improper installation. There were two problems:

1. The vertical tilt never allowed enough sunshine on the collector.For year-round optimum performance, a 35-degree tilt, not a 90-degree angle is optimum. Most of the year, there was little heat in the collector for hot water or driving the natural convection loop.
2. The plumbing lines of the collector and storage contained too many bends and direction changes. In short, there was too much friction for thermosiphoning.

The vertical tilt on the collector proved to be a mistake.

The situation was rectified in the spring of 1981. The old collectors were ripped out and two flat-plate solar collectors tilted at a 45-degree angle were installed. Each measured 2 × 12 feet.

The water in the collector was supposedly protected from freezing temperatures by the protruding glazed enclosure that surrounded them.

Apparently, the sloped collector enclosure did not fully benefit from the interior building temperature, as planned. Freezing has been narrowly averted, according to a November 1983 interview, and winter draining of the system has proved necessary.

Solar System Heated Broiler House in University Experiment at Fayetteville

Thomas R.C. Rokeby
University of Arkansas
Department of Agricultural Engineering
Fayetteville, Arkansas 72702
Telephone: 575-2351
Government Grant: $6,000

The University of Arkansas at Fayetteville Built and Monitored a Solar-heated Commercial Broiler House.

BACKGROUND

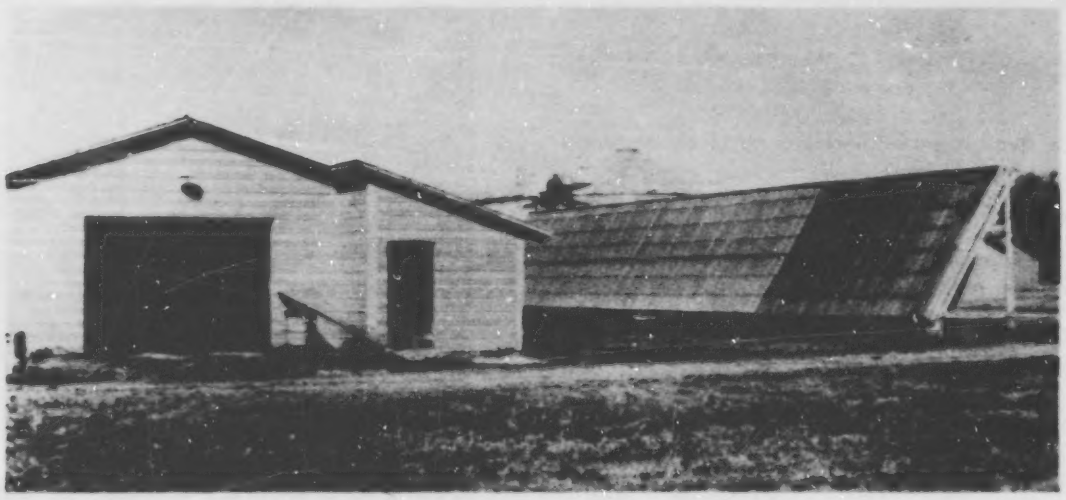
The Arkansas poultry industry, which produces about 17 percent of the nation's chickens, annually consumes an estimated 37 million gallons of liquified-petroleum (LP) gas — or its equivalent — to heat its broiler houses. At 80 cents per gallon, that fuel costs about $30 million each year.

Since 1976 this University of Arkansas research project has studied how solar and conservation technologies might reduce these fuel costs. The objectives of the study have been:

1. To develop systems and operating methods for using solar heat to brood chickens, with emphasis on retrofitting existing buildings.
2. To develop systems and methods for conserving heat energy in brooding chickens.
3. To evaluate the physical and biological performance of the proposed conservation measures and solar heating systems.

Heating a broiler house with solar air-heaters differs from using a similar system for residential application in several respects.

1. The chicken-house temperatures need to be higher — 87 degrees for the first week of a chick's life — and more uniformly maintained.



Solar collector (right) for poultry house is situated across the yard from the house itself.

2. The return air back to the collector can't come from the broiler house, as it would in a residence; it is relatively dirty, containing ammonia from chicken waste.
3. The solar collector array needed for the broiler house will have to be much larger than one built for a home because broiler houses are generally much larger, typically 40 × 300 feet.

BUILDING DESCRIPTION AND ENERGY CONCERNS

The poultry house in the experiment is typical of recently-built commercial broiler houses in the area, although it is smaller — 40 × 150 feet — and more energy-efficient. Otherwise, it's a conventional steel-frame poultry house with metal roofing and siding.

The house can hold 8,000 chicks from one day old to eight weeks of age. There is an opening in each side wall measuring 3 × 145 feet, which is closed by an adjustable woven curtain. There is R-10 insulation provided by 1¼ inches of urethane foam board applied under the roofing and siding. Most area poultry houses are insulated only to a value of R-4 to R-8.

Other energy conservation measures were incorporated:

1. Construction joints at eaves and ridges were sealed with sprayed-on urethane foam to minimize infiltration.
2. A movable insulated partition was installed to divide the house into two equal parts. Only half of the house is used for the first three to four weeks of care in cold weather. This reduces conducted heat loss by almost 50 percent during this period.
3. Removable panels of rigid insulation are fitted into the curtain openings for the first three to four weeks of care, in cold weather.
4. Curtain openings were limited to three feet high. An automatic curtain controller is used to adjust the curtain opening in reponse to house temperature.

COLLECTOR

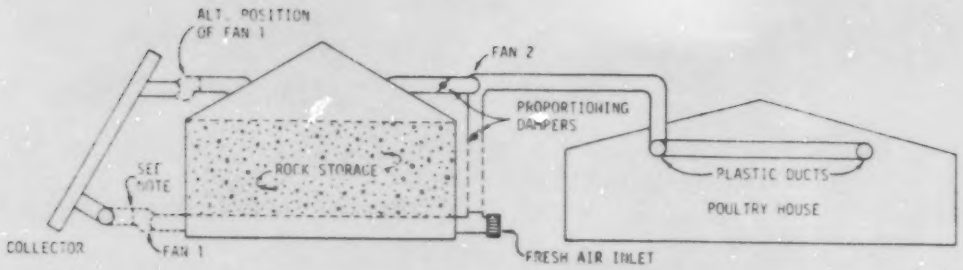
The unit has 2,000 square feet of solar air-heater, composed of two halves joined by the air-handling system, that heats the ambient air. It measures 12 × 170 feet. The collector is mounted on a treated timber rack at a 56-degree south-facing angle.

The frame is of 2 × 4 stud construction. The back enclosure is made of poultry netting, roofing felt and polyethylene film; that serves as a barrier to air infiltration. The space between the 2 × 4s is insulated with R-11 fiberglass. The absorber is blackened galvanized sheet metal. A computer study, employed to optimize thermal performance, led to a multi-stage collector design. The glazing is both corrugated and flat sheet fiberglass-reinforced plastic (FRP).

STORAGE

Heat storage consists of a steel grain-drying bin filled with 200 tons of coarse crushed limestone — ¾ of an inch to 2 inches size. The bin is 15 feet tall, and 21 feet in diameter. It is insulated with 2½ to 3 inches of urethane foam.

Rocks in this grain bin absorb heat from the collector and store it until needed in the poultry house.



Schematic arrangement of the solar heating system. Actually the collector faces the poultry house but is shown out of place for clarity. **Note:** *Ducting shown by dashed lines was removed and Fan 1 was moved to its alternate position in 1980.*

CIRCULATION AND DISTRIBUTION

Fan 1 continuously circulates 4,000 cubic feet per minute (CFM) of air between the bin and the collector whenever the temperature differential across the collector is suitable and the heated air is above a set temperature.

Fan 2 delivers heated ventilating air to the house where it is distributed within the building by a positive-pressure system. The system uses two perforated plastic ducts, which run the length of the building and are located just below the roof.

CONTROL

Fan 1 is controlled by a differential thermostat in series with a simple thermostat. Fan 2 is governed by a proportioning timer. The temperature of the delivered air is controlled by a pair of linked, proportioning dampers, which mix varying amounts of unheated air with heated air from storage. The solar heating thermostat is set to maintain 87 degrees for the first week; it reduces the temperature in steps to 65 degrees by the time the birds are six weeks old.

AUXILIARY ENERGY SYSTEM

Standby heating comes from 16 open-flame, natural-gas-fired brooders. Each has a capacity of 25,000 Btu's per hour. These come on automatically if the house temperature drops three degrees below the desired temperature.

Sun Heats Alabam Poultry House

Kevin Hatfield
P.O. Box 113
Huntsville, Arkansas 72740
Phone: 738-6786
Project Grant: $2,500

Solar air collectors partially heat a 30 × 375-foot broiler house near Alabam. The heaters measure 384 square feet. The system, designed and built by science students at nearby Huntsville High School, consists of three single-glazed, 8 × 16-foot roof-mounted panels.

These deliver heated air through 12-inch ducts into the house, with the help of fans. The system was completed in May, 1980. The project was funded by a grant from the Arkansas Energy Office.

According to Rock Hatfield, owner of the chicken house, the solar installation saved $900 in liquified-petroleum (LP) gas fuel costs during the first year of operation. "A massive hailstorm damaged the Filon glazing and this was replaced by tempered glass," Hatfield said in an October, 1983 interview.

PERFORMANCE AND OPERATING HISTORY

The collector described above has been in operation since mid-1981. Before that, a slightly different design of the same size and of similar efficiency was employed.

The new design performed admirably although it cost only half as much as the previous collector, according to Rokeby in a September, 1983 interview.

The following conclusions were based on the 1977-1981 operation of the original design:

"Live weight and feed conversion of the birds from the solar house were significantly better than those from comparison flocks. The solar-heating system provides from 42 to 72 percent of the auxiliary heat required for birds brooded in January and as high as 100 percent in warmer seasons. Approximately 80 percent of the solar heat is delivered indirectly via storage. Therefore a system designed without provision for storage would be able to provide only a small fraction of the heating requirement."

The rock bin storage proved to be extraordinarily efficient.

The position of Fan 1 was changed after it was realized that the temperature of the air returning to the collector from storage was frequently below the outside air temperature. This was due to the temperature stratification in storage and the fact that the lowest — and coolest — part of storage would cool down to the previous night's temperature.

There were no great maintenance problems and the electrical and mechanical components were quite dependable. There was some evidence of storage becoming plugged (with dust or other airborne contaminants) as the air volume delivered by the blower decreased 25 percent over the four-year period.

LIST OF MATERIALS AND COST FOR 1000-SQUARE-FOOT COLLECTOR (1981 Dollars)

DESCRIPTION	COST
Lumber	$ 310
Plywood	118
Roofing Felt	62
Sheet Metal, 29-Gauge	723
Poultry Netting	110
Fiberglass Plastic Glazing	747
Fiberglass Insulation	132
Fasteners	148
Nails	36
Silicone Caulk	80
Closure	63
Paint	44
Other Materials	30
	$2,603

Rokeby analyzes data in the course of solar poultry-house experiment.

COSTS AND BENEFITS

The original collector cost $8.50 per square foot, including installation and labor.

Efforts to reduce the cost and maintain the performance of the second collector succeeded. That one was built in two 1,000-square-foot sections.

The construction was performed by relatively-unskilled labor and required 440 worker hours.

At the rate of $4 per hour, the current area average for unskilled labor, the labor cost is $1,760.

The total cost of the new collector was $4,360, and that saved $4,140, compared to the first one, representing a cost reduction of 49 percent.

Rokeby concluded that with adequate conservation practices, a solar-heating system can reduce the fuel requirements for brooding chickens in the Southwest United States by about 70 percent.

No detailed study has been made to determine the payback period for an investment in a solar heating system like this one.

If it is to be used for space heating alone, such an investment will be attractive to some at current LP gas prices, provided the collector costs can be kept down.

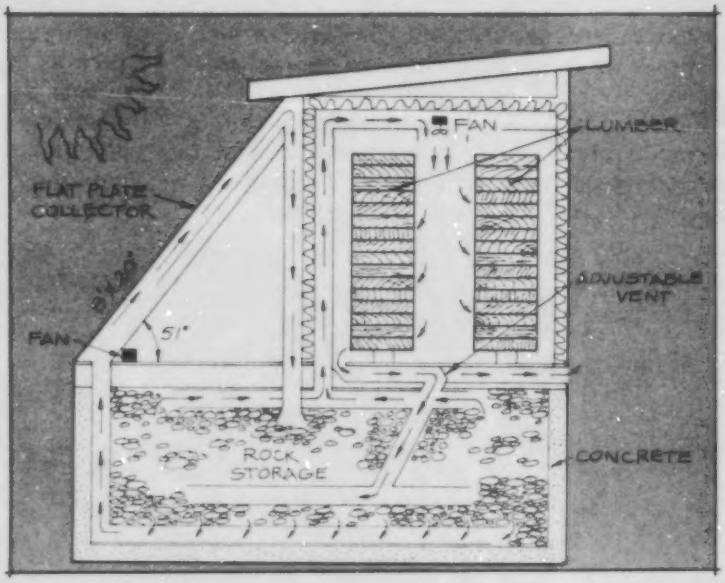
One problem is that solar arrays sized to meet mid-winter heating requirements will have unused capacity during much of the year. Finding another application during those times, such as heating water, will improve the economics considerably.

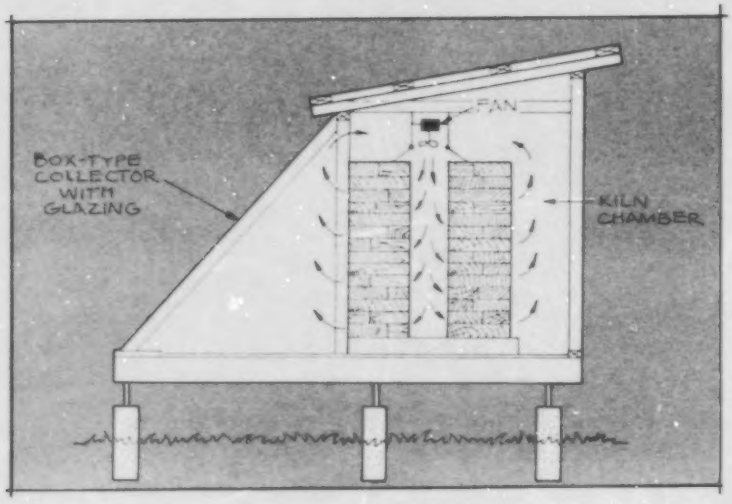
Rokeby can provide reprints of technical papers about the research project that were published in *Transactions of the American Society of Agricultural Engineers.*

Solar Energy Dries Furniture-grade Lumber in Kilns at Ozone and Eureka Springs

Arkansas Energy Office
One State Capitol Mall
Little Rock, Arkansas 72201
Telephone: 1-800-482-1122

The Ozone kiln (right) is a wood-sided building housing a collector on the south facade. The collector is double-glazed and vented to a storage area filled with rocks. Vents and fans control the passage of heat. The kiln has a capacity of 1,500 board feet. An average winter temperature of 80 degrees has been achieved. Details of the kiln are available in the book Solar Lumber Kilns, *which may be ordered without charge from the Arkansas Energy Office.*





The Eureka Springs kiln (left) uses only circulation fans and is notable for its construction — it is up on posts. The collector could be taken from the kiln and transported to a new location by truck, and the kiln could be moved separately as well. Details of this design also are available in Solar Lumber Kilns.

Rex Robbins Taught How to Build a Flat-plate Solar Collector, Including Absorber Plate

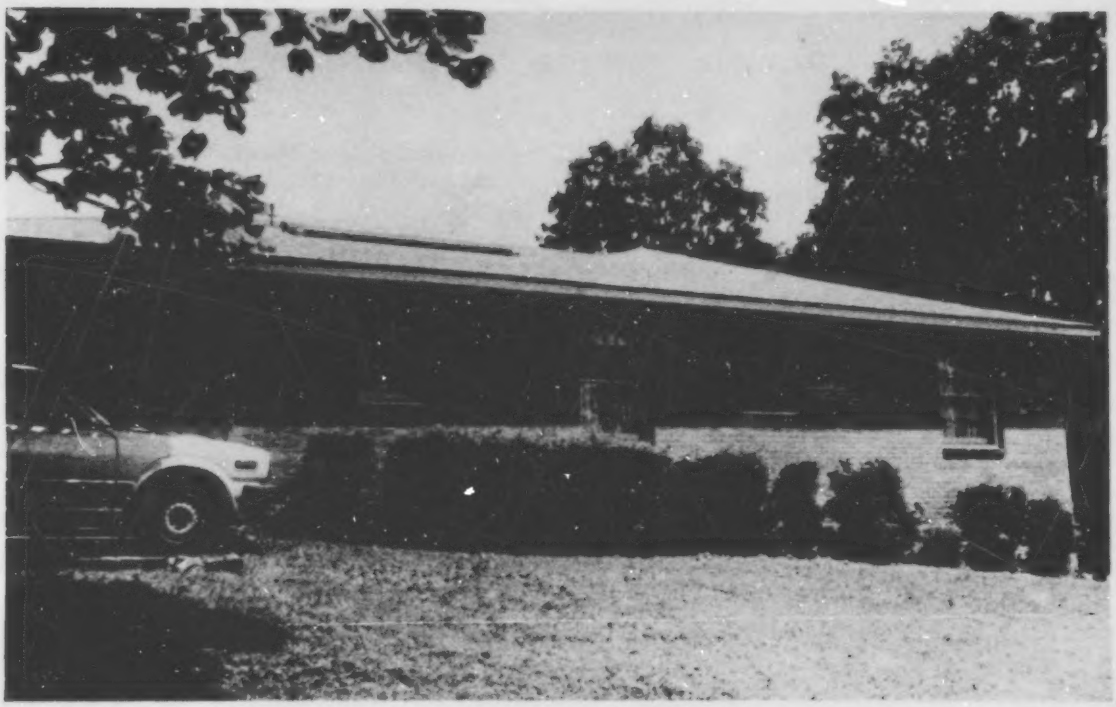
Rex Robbins
1613 East 31st Street
North Little Rock, Arkansas 72116
Telephone: 753-2650
Government Grant: $1,500
Collector Robbins Built at the Workshop Is the Same Type He Installed at His North Little Rock Home.

BACKGROUND

In April, 1981, Rex Robbins instructed a class of 12 persons in building solar collectors. One 4 × 8 flat-plate collector, including the absorber plate, was built.

The collector was designed to be easy to build, with locally-available materials. Such a collector was later installed by Robbins as part of an open-loop, pumped solar water-heating system on his North Little Rock home.

The collector construction can be viewed in two phases: Frame construction and absorber-plate construction.



The solar collector at the Robbins home is almost invisible from the street, proving that use of appropriate technology does not have to involve large, unsightly machines.

MATERIAL FOR COLLECTOR FRAME

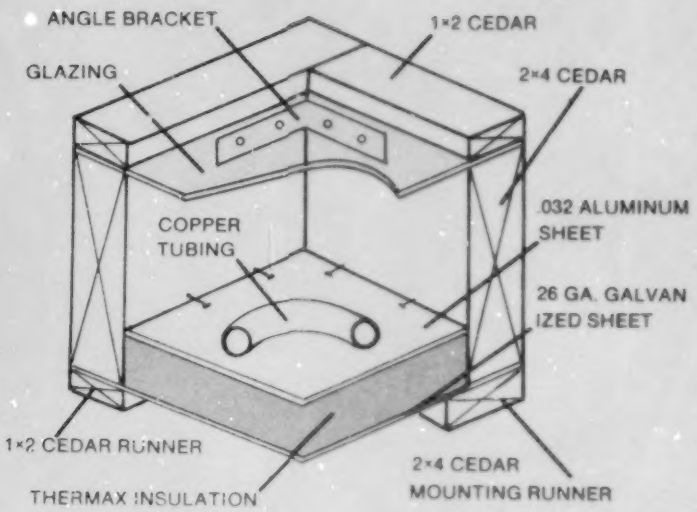
Quantity	Material
Two	cedar, 1 × 2 inches × 8 feet
Two	cedar, 1 × 2 inches × 3 feet 9 inches
One	glazing panel, 4 × 8 feet
Two	cedar, 2 × 4 inches × 8 feet
Three	aluminum angles, 1 × 1 inch × 4 feet
Three	cedar, 1 × 4 inches × 4 feet
Two	cedar, 2 × 4 inches × 3 feet 9 inches
One	26-gauge galvanized sheet, 4 × 8 feet
Two	cedar, 1 × 2 inches × 7 feet, 8½ inches
Two	cedar, 2 × 4 inches × 5 feet
One	rigid insulation, 4 × 8 feet × ⅝ inch
One	rigid insulation, 4 × 8 feet × ½ inch

MATERIAL FOR ABSORBER PLATE

Pipe Grid	
Three pieces	½-inch ID — 20 feet lengths — Type M copper tubing
Seven pieces	½-inch ID × 3-inch copper return bends
¼ pound	95-5 tin-antimony solder
one jar	flux
	Emery paper or cloth
Collector Plate	
One sheet	sheathing insulation, 4 × 8 feet × ⅝ inch
One sheet	sheathing insulation, 4 × 8 feet × ½ inch
½ gallon	Thermon cement
30	1½-inch finishing nails
20	aluminum pipe clamps
40	⅜-inch Number 10 sheet metal screws
½ gallon	heat-resistant paint or coating
One	aluminum sheet, 4 × 8 feet × 0.032 inch
Glazing	
One sheet	glazing, 4 × 8 feet
Three pieces	cedar, 1 × 2 inches × 8 feet
30	1½-inch Number 10 round head wood screws

PROCEDURE

Figure 1

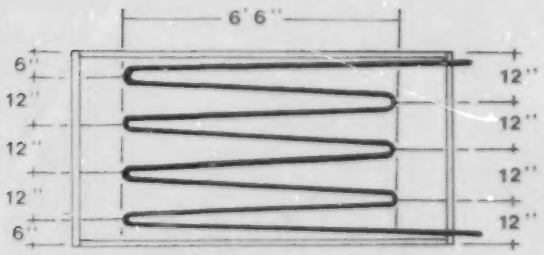


Cross-section shows corner detail of collector box.

For the collector frame, follow the work outlined in Figure 1 and Figure 4. Note that the ¾-inch-thick insulation will be cut into three pieces, to fit between the 1 × 4 braces. Over this the ½-inch-thick insulation sheet, 4 × 8 feet in size, will be laid, with the foil-side up.

For the absorber plate, follow Figure 2 and Figure 3.

Figure 2



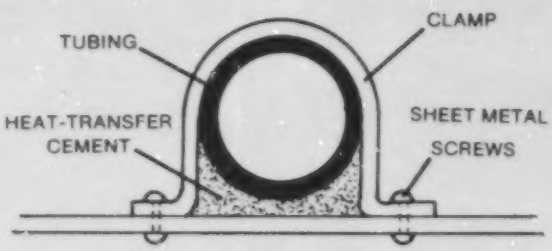
Schematic shows pipe grid layout plan. Clamps every two feet hold absorber in place (see **Figure 3***).*

To make the clamps — and to fit the absorber plate to the box — cut three inches off the length and width of the aluminum sheet. The clamps should be three inches long by one inch wide.

The Thermon cement, which promotes good thermal contact and higher efficiency, is used to bond the copper tubing and aluminum sheet. It prevents corrosion from contact of the two dissimilar metals by separating them. It is sold in cartridges of a tenth of a gallon that are easy to use and costs about the same as silicone sealant. Thermon cement is available from Solar Usage Now, Inc., of Bascom, Ohio. The absorber will need painting with a suitable, flat-black, high-temperature paint.

Finishing nails, spaced about ten inches apart, can be nailed into the sides of the frame at the edge of the aluminum plate to hold it in place without thermal buckling. See Figure 1.

Figure 3



Use of clamps and Thermon heat-transfer cement bond copper tubing to aluminum absorber without corrosion.

COSTS AND BENEFITS

Estimated collector costs are as follows:

Frame	$ 60
Pipe Grid	$ 43
Collector Plate	$ 39
Glazing	$ 36
Total Cost	$178

The immediate benefit would be to obtain a solar collector for half the price of a commercially-made collector. Negative considerations would include durability and fire resistance.

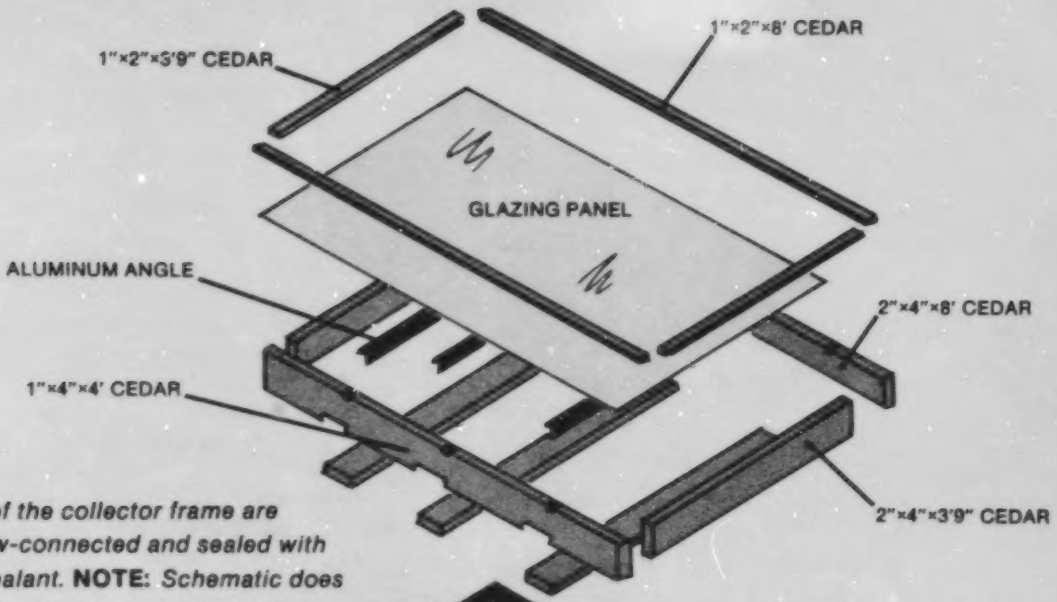
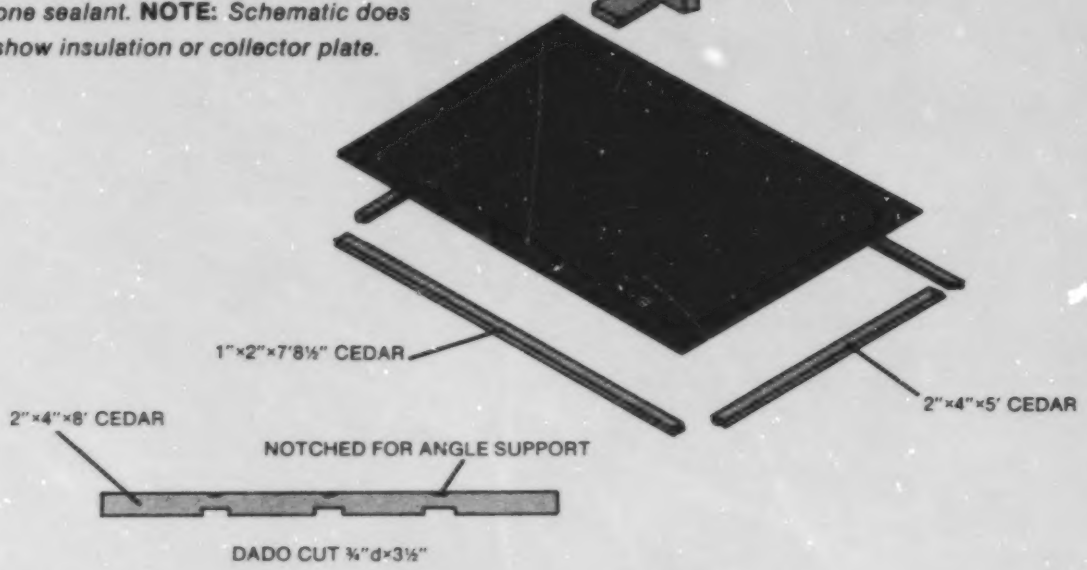
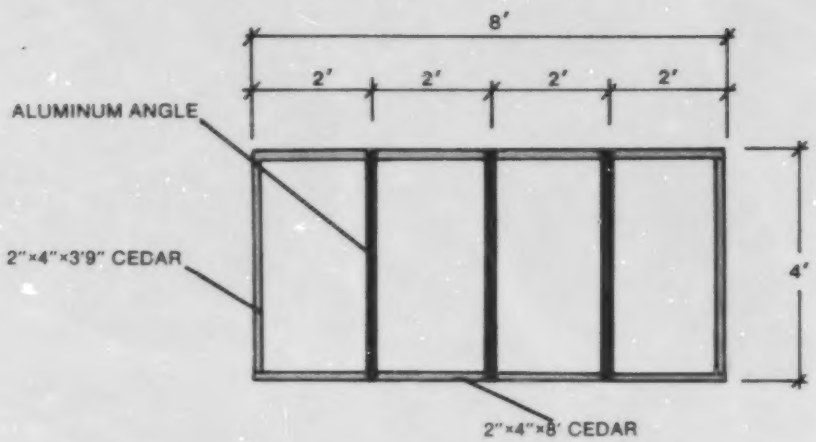


Figure 4

All joints of the collector frame are to be screw-connected and sealed with silicone sealant. **NOTE:** *Schematic does not show insulation or collector plate.*

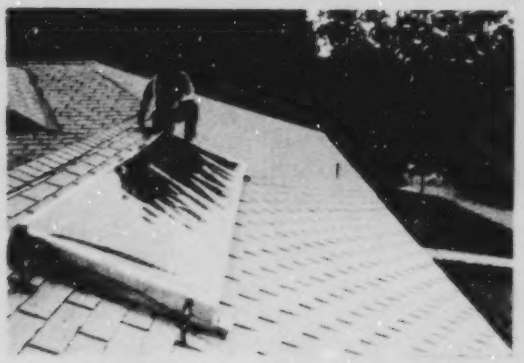




FINAL REPORT

Robbins submitted this final report on his experience to the Arkansas Energy Office:

> The purpose of this grant could properly be described as the development of owner-built solar hot-water systems. Over the course of the grant year, I have worked with several people toward this end and feel that the grant was a success.
>
> While teaching others about my experiences in building my own collector, I have learned a great deal more about the subject. I am firmly convinced that a good, reliable collector can be built by the homeowner who has a few basic tools and skills. The advantages of this approach are considerable.
>
> 1) Despite claims to the contrary, (mainly by those who have a financial interest in the solar market) this approach is considerably cheaper than commercially available units. The collector that is shown in the manual costs about $180 to build completely. Commercial units cost between 300-$400. While these units are undoubtedly more efficient, they are normally only 24 square feet whereas the owner-built collector is 30 square feet. I am confident this size difference more than offsets the efficiency difference. While the owner-built collector takes an investment in time, most do-it-yourselfers will spend hours building furniture simply for the satisfaction involved. Building my own solar system has given me more satisfaction than any other thing I have built.
>
> 2) A major advantage, often overlooked, is the fact that the homeowner can often do his own maintenance. Over the life of the system, this could prove to be a significant sum of money.



Rex Robbins checks on the solar water-heating collector at his North Little Rock home.

> 3) Another advantage arises from the fact that a person cannot build a system without understanding how it works. With his understanding, it is often possible to maximize the efficiency of the system. Recent figures that I have seen, which show a low net gain of energy for installed systems, tend to support this conclusion.
>
> In short, I feel that, while not for everyone, owner-built systems should be given more credibility and encouragement.

VISTA Workers Learned to Construct a Flat-plate Solar Collector

New Life Farm
Drury, Missouri 65638
Telephone: 417-261-2553
VISTA Volunteers Trained Low-income Families to Construct Solar Collectors After Training.

BACKGROUND

Community Energy Futures of Little Rock, now defunct, conducted workshops for VISTA volunteers on various solar-energy devices, in March and April of 1981. After training, the volunteers spread that skill to Arkansas residents in the course of their service in the state. The instructors were the New Life Farm training team.

At this workshop, attendance was 24 or so VISTA volunteers.

While these training sessions involved many hands-on building projects, including solar greenhouses, solar air-heaters, movable insulation, and solar food dryers, this report concentrates on the low-cost 8 × 8-foot **plastic pipe absorber flat-plate collector** that was built.

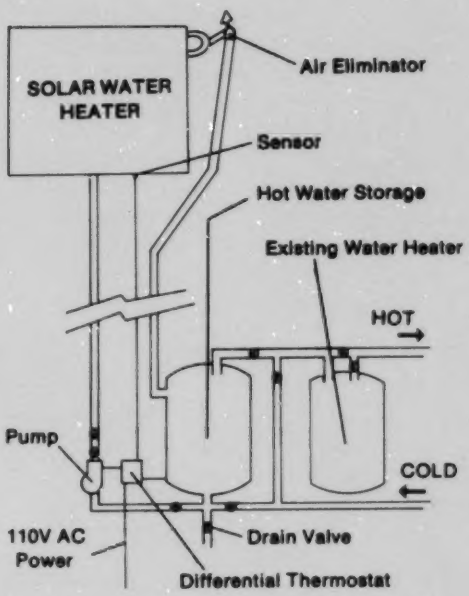
The plans are based on the original plans developed by New Life Farm for the workshop.

This low-cost heater uses polybutylene plastic pipe, which can freeze and thaw repeatedly, without damage. This eliminates the need for freeze protection by automatic draindown or antifreeze and double-wall heat exchangers. Additional savings are possible by use of a home-built differential thermostat.

A typical installation includes the roof-mounted collector, a large insulated storage tank, and the necessary plumbing, wiring, and controls. The storage tank is installed in series with the existing or backup water heater.

If the collector is not meeting household needs on a cloudy day or with unusually high demand, the back-up system comes on to supply the balance needed. The system is controlled by a differential thermostat, which senses the temperatures of water in the storage tank and water in the collector. When the collector is 10 degrees hotter than the storage, the pump is energized and water flows from storage through the collector, absorbs solar heat, and returns to storage. When the temperature of the collector drops below three to five degrees greater than that of storage, the pump is de-energized and will not come on until the collector is warm enough.

The blower on the back of the collector is designed to cool the collector if it becomes too hot. Polybutylene will soften and may rupture at temperatures greater than 180 degrees. This temperature will not be exceeded when water is flowing but may be if the pump turns off on a sunny day. A temperature sensor energizes the blower when the temperature exceeds 160 degrees, to eliminate this problem.



Plumbing schematic for solar water heater.

MATERIALS

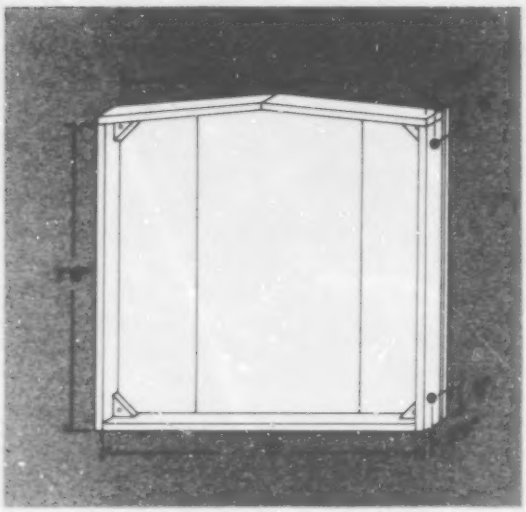
The following will be needed for one 8 × 8-foot solar collector system.

Quantity	Material
4	2 × 6s, eight feet long — for outer sides of box
1	2 × 8, eight feet long — rip down for three glazing supports; or use three 2 × 2s, eight feet long
2	4 × 8 sheets one-inch fiberglass ductboard insulation, foil faced — for back of collector
5	8 foot × 1 inch aluminum strips — to fasten glazing or flat trim
2	8 foot × 1 inch aluminum angle iron or exterior corner trim
16 feet	48-inch plastic glazing material with fiberglass reinforcing, such as Kalwall
80	Number 8 × 1 inch round head aluminum wood screws — to fasten glazing
½ pound	Number 16 galvanized box nails
1 pound	Number 8 common nails
1 pound	Number 6 common nails
500 feet	½-inch black polybutylene pipe from Vanguard Plastics Inc. 831 North Vanguard Street McPherson, KS 67460
4	½-inch polybutylene Ts
2	½-inch polybutylene 90-degree elbows
6	½-inch polybutylene in-line valves
1	½-inch polybutylene drain valve — for storage tank
2	½-inch polybutylene female to male pipe adapters
1	½-inch air vent/eliminator such as B & G 1067 from Solar Usage Now P.O. Box 306 Bascom, OH 44809
Miscellaneous	pipe fittings to adapt to existing plumbing
1	water-storage tank suitable for hot potable water at 80 psi
24 feet	3½ × 23-inch-wide fiberglass insulation with Kraft paper for storage tank
50 feet	14/2-G NM electric cable
4	Romex connectors
1	Circulating pump suitable for hot water, such as Teel IP965 (Grainger's)
1	squirrel cage blower such as Dayton 4C440 (Grainger's)
1	fan control with five-inch probe such as Dayton 2E232 (Grainger's)
1	differential thermostat such as catalog number 1550 from Solar Usage Now
50 feet	18/2 thermostat wire — for temperature sensors
1 tube	weatherproof construction adhesive
1 tube	silicone caulk
1 can	high-temperature flat-black spray paint
2	4 × 8 sheets ½-inch CDX plywood
2 feet	1 × 6 pine
50 feet	tie-wire (22 - 16) or plastic perforated plumber strap
10 feet	8-inch-wide aluminum flashing
4	⅜-inch × 6-inch bolts with washers and nuts
4	1 inch, Number 10 wood screws for blower

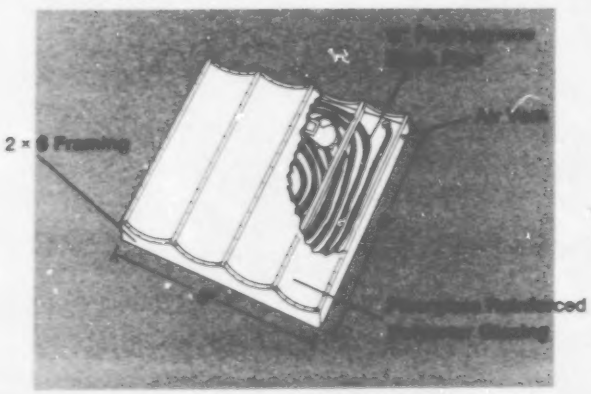
PROCEDURE

Construction of the Collector

1. Cut 2 × 6s for the frame; 7 feet 6 inches long for the two side pieces, and 7 feet 8 inches long for the bottom.
2. Cut two pieces of 2 × 6 for the top, 47½ inches long at a 5-degree angle on both ends.
   Note: The top of the collector is peaked at the center to prevent pooling of water.



3. Cut scallops in the 2 × 6s. Use a 4 × 8 sheet of plywood and string and pencil as a compass.
   Note: The top and bottom 2 × 6s are scalloped on the front edges to form a concave so the plastic glazing will withstand the stress caused by the rain and snow.



4. Cut the scallops with a reciprocating saw or sabre saw, then sand or plane the corners indicated to avoid cracking the plastic glazing.
5. Nail and glue collector frame together using Number 16 galvanized box nails and construction adhesive.
   Note: It is important to glue all joints on the collector with construction adhesive to maintain tight joints under the stress of heat expansion and contraction.
6. Cut one 4 × 8 sheet of plywood in half lengthwise, nail using Number 8 nails, and glue so the side edge and bottom edge are flush with the outside edges of the frame.
7. Nail and glue the full sheet of plywood next to the first half sheet with the bottom edge flush.
8. Nail and glue the second half sheet.
9. Trim the excess plywood on the top and side.
10. Nail, using Number 6 galvanized box nails, and glue five 1 × 2 strips, each measuring 8 feet, to the back, flush at the bottom edge and extending past the top edge. Center the second and fourth strips on the plywood seams. Trim the excess at the top.
11. Cut four corner braces from the leftover 2 × 6 pieces. Nail and glue these in the corners.
12. Drill a ½-inch-diameter hole through each brace for mounting bolts.
13. Drill four ⅜-inch-diameter drainage holes at the bottom just in front of the plywood back.
14. Drill two 1½-inch-diameter holes for air vents in each side. Cover with screened vents.
15. Cut one-inch fiberglass ductboard to fit inside the 2 × 6 frame, tight against the back.
16. Drive Number 6 nails above ductboard. Put the heads about ½ inch above the ductboard.
17. Spray paint the ductboard and inside frame with heat-resistant flat-black paint.
18. Paint the sides and back of the collector with weather-resistant, fast-drying paint.
19. Beginning from the top left-hand corner, wind two parallel spirals of polybutylene

pipe around the nails, strapping the pipe to the back with tie-wire from one nail head to the next. Leave about three feet of extra pipe at the outer end to extend through the back for connections. From the center, extend both ends radially toward the top right-hand corner and leave three feet extra to pass through the back at this point.

Note: All holes through the roof should be near the top of the collector to minimize the possibility of a leak within the collector that would drip into the attic.

20. Cut three 2 × 2 glazing supports to fit inside frame. Nail, using Number 16 galvanized box nails, and glue and paint black.

Installation

1. Mount the collector on the roof using 6-inch bolts.
2. Drill two ¾-inch holes at the top left corner, and two at the top right corner, for the polybutylene pipe, and push the ends down through the roof.
3. Install the blower, and put the fan control probe inside the collector. Provide a six-inch-square opening for blower duct. Have a competent electrician wire this in.
4. Using flashing, silicone or plastic roofing cement, weather-proof the collector and roof.
5. Install Kalwall glazing, following manufacturer's instructions.
6. Install the other system components.

PERFORMANCE AND OPERATING HISTORY

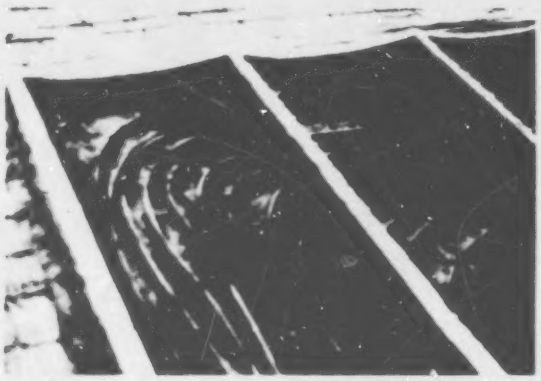
The workshop-built collector was installed at Stepping Stone in Little Rock, a half-way house for teenagers. It operated without problems for approximately one year before the building was razed for a new development project.

A similar plastic-pipe-absorber collector has operated at New Life Farm, at Drury, Missouri since 1980. The pipe has frozen and thawed many times with no problems. There have been no leaks in the entire system.

The collector box, built of 1 × 6 painted pine, has deteriorated in the weather, and its replacement is planned. This collector employs 1,000 feet of plastic pipe.

An earlier collector without blower or ventilation provisions operated from 1978 to 1980. A pump failure led to collector stagnation and a "melt-down". It was replaced with the improved design.

The 8 × 8-foot collector detailed here will provide all the hot water needs of an average household on a sunny day.



The scalloped construction of the collector enables the plastic glazing to withstand stress of rain and snow. Spirals of polybutylene pipe are cooled by a blower when temperatures exceed 180°.

COSTS AND BENEFITS

The collector alone can be built for around $250. A complete system can cost $500 to $1,000, depending upon the tank employed and other component choices.

Depending upon location, household size and hot water usage, the system can provide 50 to 80 percent of the hot water needed. However, the collector lifetime is somewhat uncertain, since only limited operating experience has been acquired.

Community College and Energy Office Taught Construction of Solar Collectors at Harrison

North Arkansas Community College and the Arkansas Energy Office
Nick Brown
Arkansas Energy Office
One State Capitol Mall
Little Rock, Arkansas 72201
Telephone: 371-1370 or Energy Hotline: 1-800-482-1122
Project Grant: None
Solar-energy Experts Taught Arkansas Residents How to Build Their Own Collectors.

BACKGROUND

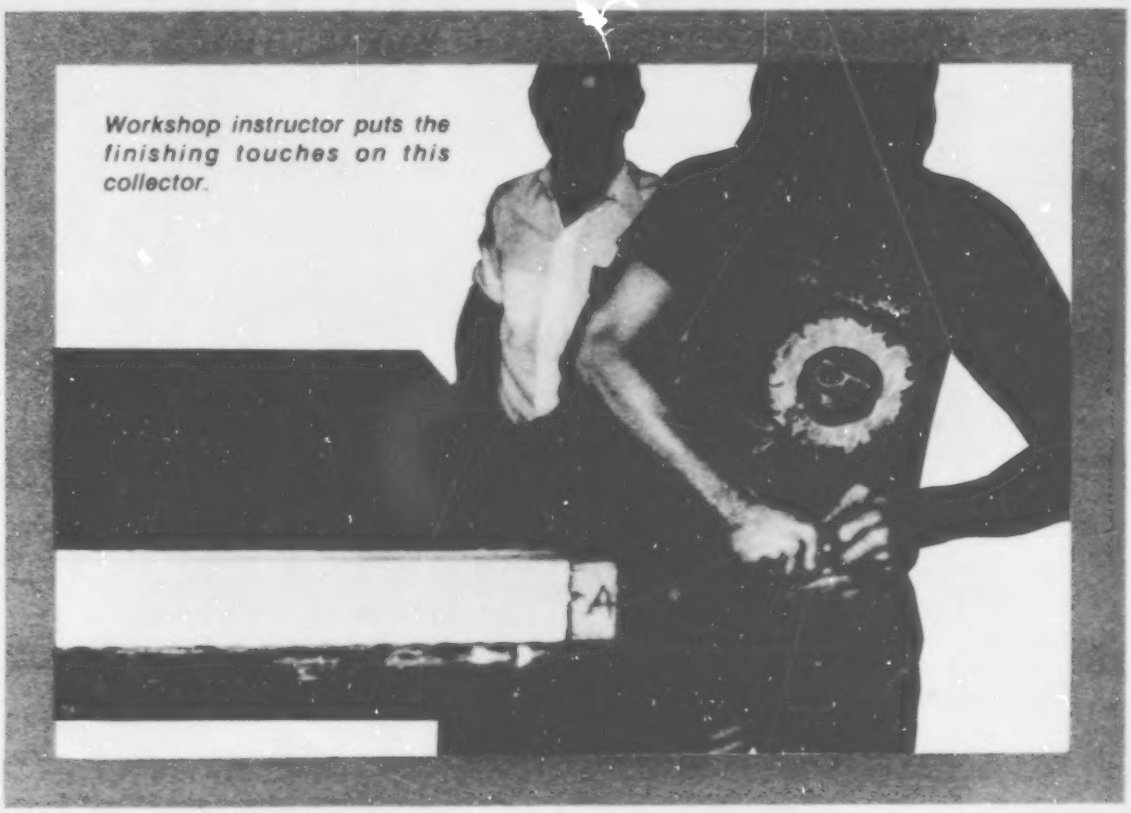
In August, 1982, instructors Nick Brown, Stephen Cook, and Ron Winkle conducted a workshop on how to build solar collectors.

Attendance was 26.

Four 34 × 76-inch flat-plate collectors (liquid-type) were built, using commercially-made absorber plates.

The collector design built here was based on the use of 34 × 76-inch patio-door replacement glass, which is widely available and inexpensive, and a similarly-sized Phelps Dodge all-copper tube and fin high-efficiency absorber plate.

This absorber has eight risers on four-inch centers and is available unpainted, painted flat black or with a (selective) black chrome surface. The chroming process adds about $1.30 per



Workshop instructor puts the finishing touches on this collector.

Solar Collectors Serve Summercorn Bakery at Fayetteville

David Druding
Summercorn Bakery
401 Watson Street
Fayetteville, Arkansas 72701
Telephone: 521-2164
Project Grant: $500
Thirty People Learned to Build Solar Collectors at a Workshop.

In a similar workshop, aluminum-frame collectors were produced.

Thirty people attended this workshop in Fayetteville, which was instructed by Nick Brown of the Arkansas Energy Office and sponsored by Summercorn Bakery.

Two collectors were assembled, which were very similar to those built at the earlier workshop. However, while 34 × 76-inch glazing and Phelps-Dodge absorber plates were again part of the design, aluminum, not wood, was used for the collector side frame.

Specifically, EASCO-extruded aluminum, made for a collector asembly, was employed.

Pieces of this aluminum were cut using a metal-cutting blade in a bucksaw. A miter box was used for corner joints. Holes were drilled and aluminum screws were used for the collector frame assembly. Twelve-gauge aluminum was used for the backing.

The glass was fitted using EPDM gaskets and a clear silicone sealant.

The finished collectors are more aesthestically pleasing than the wood-framed ones.

The aluminum should weather better than the cypress wood and provide a longer life for the collector. However, the aluminum side frame adds about $40 over the cost of a wood-framed collector.

The collectors built at this workshop were installed on the roof of Summercorn Bakery in Fayetteville. They are part of a somewhat unconventional, but low-cost draindown system, which employs a homemade tank-in-tank heat exchanger. This part of the system does not conform to state plumbing codes and is not recommended by the Arkansas Energy Office.

The system cost $600, excluding labor.

square foot to the cost and about 5 to 10 percent efficiency to the collector's performance at most temperatures.

MATERIALS

The workshop used 2 × 4 cypress for the collector frame, 0.025-inch aluminum for the back, binderless fiberglass insulation (Owens-Corning SI-100), small pieces of Thermax insulation, 34 × 76 × 3/16-inch tempered patio door replacement glass, silicone caulking, a Phelps Dodge absorber, and miscellaneous hardware.

PROCEDURE

The 2 × 4 collector frame sides are dadoed out to accommodate the absorber plate, glass and back, using a router. The frame is screwed together with 3½-inch wood screws. The back fits into a dado joint about ¾ of an inch into the side frame.

It does not need to be sealed; this loose construction allows the collector to breathe.

Gussets are added on the corners and cross-pieces attached at intervals along the back, to make the case rigid. The space between the absorber and back is filled with fiberglass insulation, and Thermax is used as a spacer to keep the absorber and back two inches apart.

To accomplish that, small pieces of it are placed every 18 inches or so down the center of the collector, and attached with construction adhesive.

Thermax can also be used on the side above the absorber to isolate the absorber from the frame. After fitting the glass into the frame, a bead of silicone caulk is used to seal it to the side frame.

PERFORMANCE AND OPERATING HISTORY

The performance should come close to a commercial collector that employs the same absorber plate, and that should be far superior to most homemade absorber-plate collectors.

COSTS AND BENEFITS

The cost of the collectors built at the workshop was $125 each. The immediate benefit was a savings of **at least half** the price of a similar, commercially-made collector.

3 Passive Solar Energy

Arkansans Found Comfort and Economy in Earth-sheltered and Passive-solar Houses

The Arkansas homebuilding industry is incorporating solar features into new homes in response to public demand, and that number is steadily increasing.

From an uncertain beginning in the early 1970s, Arkansas solar homebuilding has matured. Often, designers and builders can rely on past experience with similar houses to predict what a client's utility costs will be before the home is built.

Computing payback periods for the added investment in a home's solar and conservation features can be very complicated. However, most new homebuyers will respond to the promise of lower monthly utility bills, if the home selling price is reasonable, as our case histories bear out.

In the effort to reduce utility bills even further, today's Arkansas solar homes offer more features than lots of south-facing windows and plenty of thermal mass, although successful homes do fit this simple description.

Sometimes the new buildings employ **both** passive and active space-heating collectors. A more frequent new combination is passive space-heating and active water-heating systems. Another practice blends active space-heating with passive water-heating. New remote or vacation homes may combine passive solar features with a renewable electrical system. Finally, some new homes may be passive solar/underground hybrids, or incorporate thermal envelopes.

There are mild earth-tempering approaches — earth berms — and there are homes completely underground, with only an open southern exposure. The special problems posed by earth-sheltering include:

- Water proofing
- Structural considerations
- Keeping costs in line.

Arkansas' experience regarding costs is that an underground structure adds 10 percent or so to construction costs.

Benefits to underground living include:

- Quiet
- Tornado protection
- Minimal maintenance
- Superior durability

Planning to use solar energy begins with the site. Site microclimate and the building design need to work together. *Solar Site Planning* helped many builders and can help you.

The passive design can be an original one, based on the needs and desires of those who will live in the house, or it can be a design known to perform well in a similar climate.

For a more detailed performance analysis, many design professionals employ *The Passive Solar Design Handbook*, and microcomputer programs, to simplify the process.

One decision is to determine the proper balance between solar and conservation features in the building.

Solar homebuilders and architects can offer assistance here and with other concerns. For example, it is important to find a good building contractor.

Insuring that air infiltration is kept suitably low requires careful attention to detail.

To assure the structural integrity and watertightness for underground construction, demand quality workmanship. A structural engineer should also be consulted.

If you plan to build an underground home, consult *Earth Shelter Digest* for the latest product information and design and construction know-how.

Bank Financing Went to Solar Home for First Time in 1980 to Construct Little Rock House

Bob Bland
8015 Brandon Street
Little Rock, Arkansas 72203
Telephone: 565-3581
Government Grant: None

A Little Rock Home with Solar Heating Received Conventional Bank Financing, a First for the State.

PROJECT SKETCH

In 1980, Julian and Allison Sanchez obtained a bank loan that represented the first time an Arkansas bank had loaned money on a solar home — a home that lacked a conventional heating system. Bob Bland — a solar architect and Allison's father — designed the home and later maintained office space there.

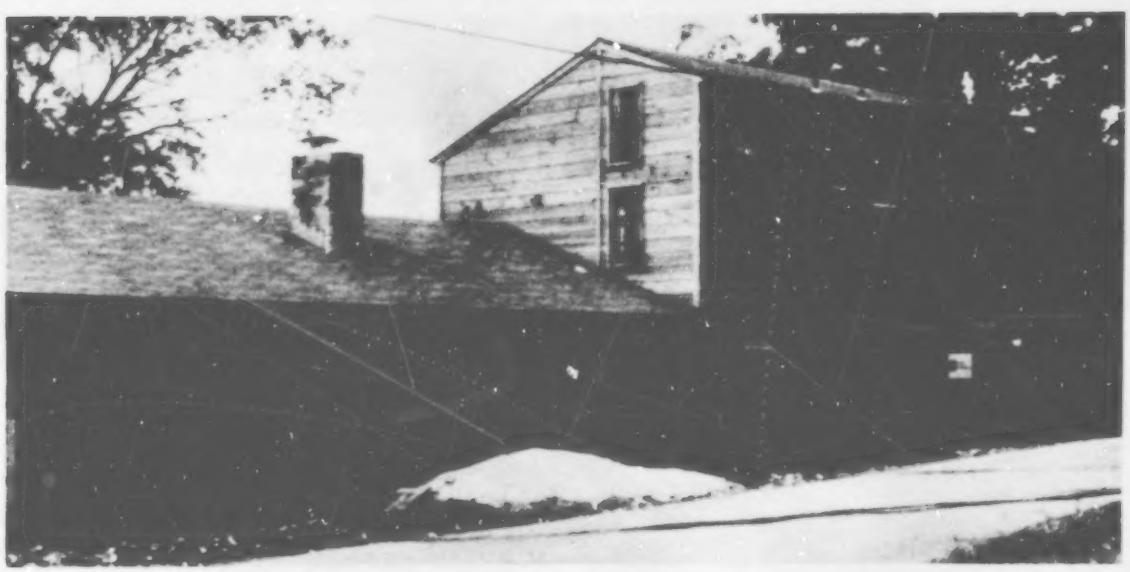
The two-story home has 2,000 square feet, and only a fireplace and woodburning stove supplement the 500 square feet of solar collection area. The vertical south wall serves as the collector.

Half of this is single glazing covering a solar greenhouse 8 × 20 feet in size, which is set off from the rest of the house by a glass partition and concrete block walls. The rest is double glazing.

A concrete floor 12 inches thick, covered by ceramic tile, and concrete block walls provide thermal mass. The well-insulated structure appears to store appreciable amounts of solar heat and to experience only small temperature fluctuations.

According to Allison Sanchez, no overnight fire is needed, yet typically the downstairs is 60 degrees on cold winter mornings. Once, after very bitter cold and three days of overcast weather, a low of 54 degrees was noted.

The lot is separated from a neighboring one by a yard fence that doubles as a corrugated,



With only a wood stove and fireplace to supplement the solar collection area, temperatures in the Bland/Sanchez home stay quite comfortable.

Bob Bland of Little Rock stands in front of one of his solar homes.

fiberglass-covered wood storage area.

Julian Sanchez estimated that two or three cords of wood were burned each year for heating. The firewood is obtained for the small investment of time running a chainsaw and a small outlay for gas, oil and maintenance.

Otherwise, electric bills for this all-electric home average around $60 per month. The water heater is the biggest single contributor to this cost.

The home is one of many designs by Bob Bland of Little Rock, a long-time builder of solar homes in Arkansas.

Most have about 1,000 square feet. Most of these employ wood stoves for backup heat. The cost is typically $42 for a square foot of living space, plus the lot cost.

Homeowners' electric bills have averaged $35 to $50 per month for these all-electric homes.

Bill Harrison Retired to Earth Home Near Jasper That Features Heating Under the Floor

Bill Harrison
Route 3, Box 84
Jasper, Arkansas 72641
Telephone: 446-2271
Government Grant: None
Design of This Passive Solar/Underground House Overcomes Common Problems.

BACKGROUND

While Bill Harrison, a retired university journalism professor, was searching Newton County for the perfect site for his undergound "dream" home, local building professionals involved with passive-solar and undergound homes were facing some major problems — whose solutions took shape in Harrison's new home.

By the time of a November, 1983 interview, the verdict was that the designers and builders of Harrison's home had been successful in dealing with some basic problems with these structures.

One problem was with heat's natural tendency to rise to the top of a building. That meant temperature stratification was always a concern.

Some occupants reported cold floors, and indications were that heat storage in or under the floor was needed.

Second, underground structures built with poured concrete take a long time for the concrete to fully cure. This can result in a structure that is too damp, or one that cannot be lived in at all, during the year or so that curing takes place.

High humidity is a problem in many of these structures.

Then there's the problem of the time and expense involved in forming up walls even before they are poured. The use of precast concrete panels could make things easier, if excessive transportation expenses weren't incurred.

Another solution is constantly-moving air, to overcome the high humidity and stale-air problems.

These solutions were incorporated into Harrison's home when he was ready to build, although more work remained to handle the details of moving air under the concrete slab floor. The heat dumping and recovery solution lay ahead.

BUILDING DESCRIPTION AND ENERGY CONCERNS

The 2,400-square-foot house has living area on one level, totally buried on three sides, which is open to the south.

Penetrating the earth over the concrete roof is a second-story, isolated structure, which measures 8 × 16 feet.

This tower room is important because of its role both in heat storage and recovery, and in the cooling of the building. The building return air is located here, and the glazing powering a thermal chimney is here, as is lots of heat storage.

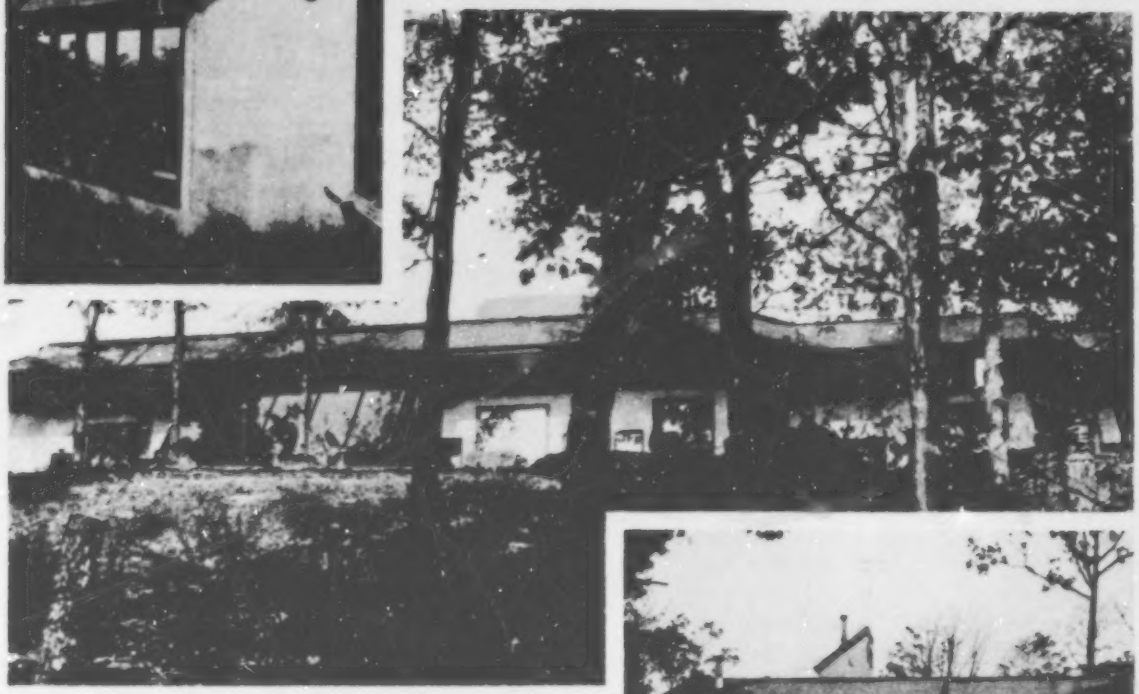
The tower room will also be the location of a two-tank batch solar water heater, soon to be installed. A door on the tower's north side provides access to the rooftop garden and firewood cutting area.

The wood-cutting area permits easier delivery to a storage area near the main wood stove on the lower level. Harrison tosses wood down a chute that connects the tower and lower level. This minimizes wood-handling hassles, which can be great with below-grade living.

The tower is insulated to a value of R-20 in the walls and R-39 in the ceiling.

Structurally, six-inch-thick precast concrete panels compose walls.

The roof was poured over metal decking. Both ceiling and floor slabs are four inches



The passive collection area of Bill Harrison's home (center) faces due south, as does the double glazing of the tower (upper left). A shop area heated by a wood stove separates the east-end garage (lower right) from the main living area.

thick, and the floor slabs are isolated from the earth by one-inch Styrofoam extruded insulation beneath them.

The first four feet below grade of the wall surface is insulated on the outside with three inches of Styrofoam; the next four feet down, with two inches of Styrofoam; and the last four feet, with one inch of the same.

The roof is covered with four inches of Styrofoam and two feet of earth. Bentonite was troweled on for the waterproofing.

The main entrance is through an air lock on the south side. The structure's only windows are on the south side, as is the solar greenhouse.

The garage is below grade at the east end of the building. A shop area with another wood stove separates the garage from the main living area.

The home has all-electric utilites. Sixty feet of ¾-inch copper tubing embedded in the tower heat storage preheats the water going to the electric heater.

Harrison cooks with a microwave oven, and occasionally an energy-efficient wood stove is used in winter.

Fluorescent lighting was installed, which uses less power than incandescent bulbs.

While Harrison lives alone, he has frequent company. Visitors occupy quarters with a separate kitchen on the building's west end.

PASSIVE SYSTEM

The passive **collection area,** all due-south double glazing, includes the following:

1. Vertical direct-gain windows totaling 300 square feet.
2. Tilted greenhouse glazing totaling 136 square feet in the 12 × 16-foot structure. Sliding glass doors form the adjoining partition wall between greenhouse and house. There are also two upper vents totaling 10 square feet on this partition wall.
3. Vertical direct-gain windows in the tower totaling 90 square feet.

Bill Harrison shows off the greenhouse of his Jasper home. The double glazing faces due south and totals 136 square feet.

Thermal mass is provided by the following:

1. In the lower level, concrete walls and floor furnish an estimated 40,000 Btu's per degree Fahrenheit thermal mass.
2. The roof concrete slab, where heat can be dumped if desired or closed off by vents if not wanted as thermal mass, provides another optional 27,000 Btu's per degree Fahrenheit storage.
3. Concrete blocks, concrete walls and floor slab in the tower region weigh 9,600 pounds and provide another 10,000 Btu's per degree Fahrenheit of thermal mass.

The building as a whole has 90 Btu's per degree Fahrenheit per square foot of collector (without employing the ceiling slab), which is twice the 45 Btu per degree Fahrenheit per square foot normally desired.

ACTIVE SYSTEM

A small 800-cubic-feet-per-minute, thermostatically-controlled Dayton blower pulls heat out of the tower thermal mass. It is sucked down through a 9 × 12-inch duct and pushed under the concrete floor. Corrugated steel decking under the floor provides a path; the air moves between the corrugations. Some heat will be dumped in the slab and be given back to the house later through the radiant floor. Some will emerge as hot air out floor registers along the south wall. How much heat emerges in that fashion depends on the floor temperature and the heat available — both solar heated air and heat in the upper thermal storage. After circulating through the living space, this air is returned — possibly with added solar heat if it is a sunny day — to the tower return-air by one of two routes.

Normally in Mode 1, it will enter the ceiling register, pass through the upper concrete block storage, the holes used as rough ducts, and back into the 9 × 12 return duct.

Optionally, in Mode 2, during warm days of abundant sun, a path between roof concrete and the lower ceiling can be employed. This will dump heat into the roof slab where it can be recovered later by the blower in similar fashion.

The mode selected is determined by which vents in the lower tower section are opened.

COOLING

Thermal chimney techniques are used for cooling. While the blower is not part of the cooling operation, the air paths employed in moving air from the living area to the tower are the same as for the active system. Relatively cool air enters through eight operable windows on the south side, totaling 40 square feet of ventilation. The exit is 80 square feet of vents at the peak of the tower room. (Note 1:2 ratio for inlet to exit).

The driving force is the temperature dif-

ference achieved by the 90 square feet of glazing in the tower. The solar-heated air in the tower rises out the roof peak exit. The upward draft created in this fashion is substantial and it pulls air up from the rest of the structure and out the peak tower exit.

Other cooling is achieved by the structure's earth-sheltering and by south wall overhangs. In the greenhouse, operable lower vents, peak vents to the exterior and a screen door keep temperatures down. A shade cloth is planned there as well.

PERFORMANCE AND OPERATING HISTORY

The house has been occupied since January, 1983. However, since the greenhouse was not completed, the structure's winter heating performance could not be fully evaluated. The system of flowing solar-heated air under the slab for radiant floor heating required professional engineering analysis and presented installation headaches, but seemed to be providing good, even heat distribution. Floors stayed very comfortable and good heat was noted out of each south wall register.

The thermal chimney functioned well during the summer, according to Harrison. However, as the tilted south roof glazing originally planned for the tower was not employed, the designer feared the tower would not work as well as predicted due to somewhat reduced temperatures.

During the first nine months of occupancy, the highest monthly utility bills were $30 to $35. The house stayed very comfortable, typically in the lower 70s throughout the hot summer of 1983, with no fans or air-conditioning. Only during the hottest August days did house guests, accustomed to air-conditioning, report being uncomfortable. This apparently was due to high humidity and lack of air movement, rather than the interior temperature. A small circulating fan was employed on that one occasion for air movement. Over-all, Harrison is very pleased with the performance and comfort achieved.

Solar engineering analysis predicts an annual solar savings fraction (SSF) of 82 percent — a measure of the portion of heating requirements being met by the passive solar system. A January clear-day temperature swing of 12½ degrees Fahrenheit is predicted within a range of 57½ degrees to 82½ degrees if no (wood) backup is used and the active system operation is Mode 1. If Mode 2 is used, with additional effective thermal mass, the temperature swing then reduces to a predicted 7½ degrees, ranging from 62½ degrees to 77½ degrees. These predictions assume night insulation of R-4 will be used. Without night insulation, the predicted SSF is 51 percent. So far the movable insulation has not been added, although it will be in the future, if deemed necessary.

COSTS AND BENEFITS

Costs for this 2,825-square-foot structure (2,400 square feet of living space and 425 square feet in the garage) escalated as the project continued. Original projections were for a finished cost of $35 to $40 per square foot.

The final, actual figure was closer to $70 per square foot. The remote location and innovative nature of the house drove costs up.

The benefits were very low utility bills, thermal comfort, and the other advantages of being mostly underground.

FOLLOW-UP INFORMATION

Contact the architect:

Jeff Laur
P.O. Box 672
Harrison, Arkansas 72601

or the solar consultant:

Stephen Cook
CompuSolar
Gum Springs Road
Jasper, Arkansas 72641

or the building contractor:

John Hefley
Highway 7 South
Harrison, Arkansas 72641

Tim Kliewer Used Earth, Solar Systems and Envelope Design in His Siloam Springs Home

Tim Kliewer
Box 999
Siloam Springs, Arkansas 72761
Telephone: 524-9495
Government Grant: $3,400
Steve Baer Book Inspired Kliewer's Design for His Home.

BACKGROUND

The Kliewer home incorporates three different approaches to providing household comfort year round in a skillfully-integrated design.

First, the home is substantially earth-covered; second, it is surrounded on its top and north sides by a thermal envelope, which is charged by the sun. Finally, the solar collector employed here is a passive convective loop.

Such collectors are well described by Steve Baer in his book, *Sunspots*, a publication that inspired Tim Kliewer.

BUILDING DESIGN AND ENERGY CONCERNS

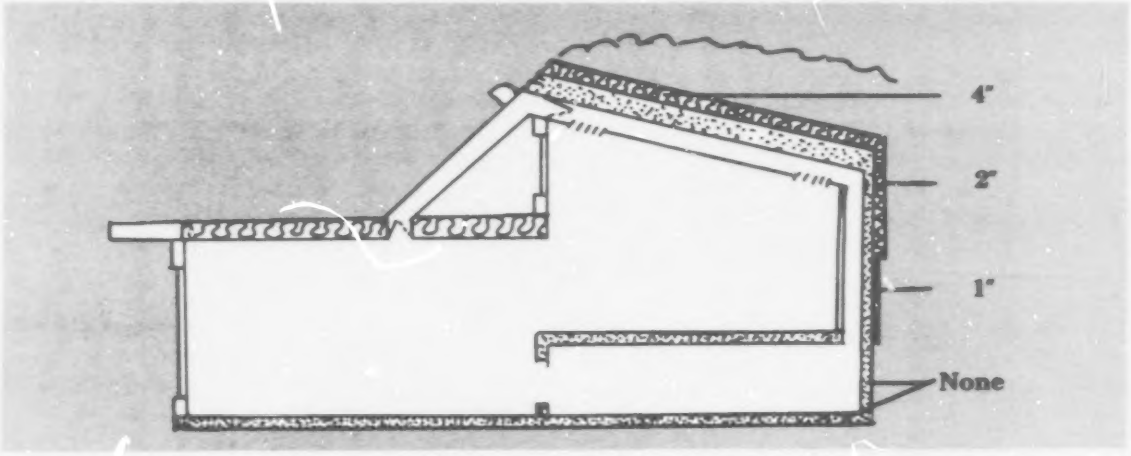
The three-bedroom house has 1,932 square feet of heated living space and 718 square feet in the garage. A cross-section of the house shows how the elements fit together. The home uses the elevational design for earth homes, and has lots of windows on the open south side.

A 10-inch thick concrete skin, waterproofed with Conklin (elastomeric) products, and insulated on the outside with Insulbead rigid board insulation, forms the structure of the house.

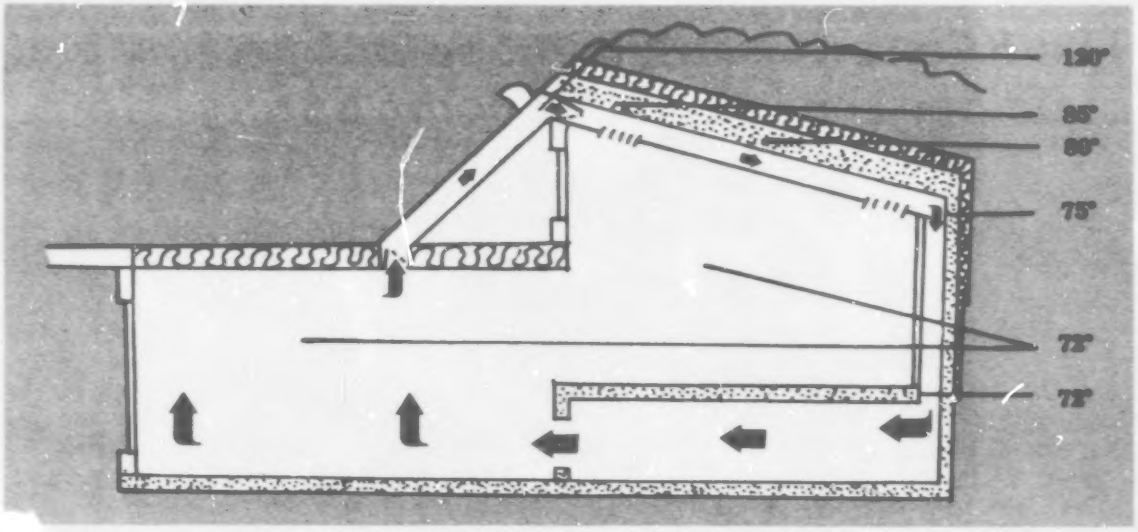
The northern (concrete) half of the roof is covered with 1½ to 2 feet of earth. The remainder of the roof is of frame construction insulated with 12 inches of fiberglass.

All windows are double-glazed and insulating drapes prevent night-time heat loss.

Common problems in underground living are high humidity and mildew. The thermal evelope, with its constantly-moving air, was incorporated partly as an attempt to overcome this. Of course the heating and cooling benefits of the envelope were of more concern, but



Cross-section shows different insulation values in the Kliewer home.



Cross-section shows air-flow and typical temperatures.

driving the air flow required a temperature differential and solar heat storage was necessary.

The variable insulation thickness over the concrete, in combination with the variable temperature of the soil with depth, create this temperature difference from the top to bottom of the loop. This difference allows the air to sink along the north wall and into the crawlspace rock storage. Tim Kliewer describes the envelope in his house and its operation this way:

"Large ducts are needed for passive air flow. A drop ceiling below the concrete roof provides a minimum space for airflow. A frame wall eight inches from the north concrete wall with numerous slots through the concrete floor opening into the rock storage provides the continuation of the airflow space. Openings two feet by two feet from the rock storage area into the lower portion of the house completes the cycle.

"When the air enters the collector intake it is heated, expands, and rises to the top of the collector. The air leaves the collector at about 120 degrees and comes in contact with the cooler concrete ceiling. The heat is absorbed and stored in the concrete ceiling. As the air loses its heat to the concrete, it contracts and falls, creating a downdraft that flows all the way through the rock storage and into the lower portion of the house, where it begins the circuit once more."

HEATING AND COOLING FEATURES

A total of 160 square feet of convective-loop, passive air-heaters is used. There are three separate collectors; two are 8 × 8 feet and the other is 4 × 8 feet. These are single-glazed with Kalwall Sunlite. The absorber is four layers of blackened steel mesh. Insulation is 1½ inches of foam glass. The collector frame is made of 2 × 12 redwood.

The collectors, which unfortunately are sometimes slightly shaded by the stone chimney, charge the thermal envelope. Thermostatically-controlled motorized dampers prevent reverse backflow.

Double-glazed direct-gain windows located on the south wall total 180 square feet. Insulating drapes cover these at night.

Earth cooling is provided largely by immediate contact of the lower envelope with the ground 10 to 15 feet below grade. There is no insulation here.

The convective-loop collectors are vented at the top to prevent their overheating the house. An overhang protects the south windows from the summer sun.

A two-foot square window fan, placed at the lower envelope openings in rock storage, is used for cooling. This can work either by drawing air in the collector vent, moving it through the envelope, and exhausting it out

the operable south windows or in the reverse direction.

The mode used depends on where cool air for inlet is available and what the concrete roof temperature is.

Mrs. Kliewer stands by the solar collectors which charge the thermal envelope of the Kliewer's home.

A 5,000-Btu, portable air-conditioner in a window of the upstairs loft is also used both to dehumidify and help cool the house.

Backup heating is supplied by the homemade, double-barrel "conversation piece" wood stove.

PERFORMANCE AND OPERATING HISTORY

Between March 1981 and July 1982, with four and sometimes five family members living in the house, including teenaged children — the average monthly kilowatt-hours used was 1,181. This represented an average monthly electric bill of $70.

The usage varied from a September, 1981 low of 833 kilowatt-hours to an August, 1982 high of 1,558 kilowatt-hours. The average January usage was 1,208 kilowatt-hours. The home uses electricity for water heating and for other typical household appliances.

The Kliewers also need electricity for a deep-well pump and a pump for the septic system. Tim Kliewer said he believed that hot-water use accounts for up to half of their monthly bill. He is planning installation of a batch solar water heater.

Temperatures at 16 places throughout the structure and underground can be instantaneously monitored through the use of temperature sensors coupled to Heliotrope electronic thermometry equipment. Records of these temperatures have been kept.

During the winter heating mode, the concrete nearest the collector peaks at 85 degrees, the center of the ceiling peaks at 80 degrees, the top of the north wall peaks at 75 degrees, and the concrete floor peaks at 72 degrees, giving a constant room temperature in the low 70s.

During the summer, the concrete roof temperature occasionally would climb over 90 degrees, making the house uncomfortable, and necessitating use of the window fan to cool it off.

Temperatures in the rock storage area varied only from 56 to 75 degrees during the two-and-a-half years of monitoring. The 56 degrees was measured on December 30 after a one-week absence. These rocks are not effective at storing winter heat but can help out with summer cooling.

Natural airflow rates in the envelope have also been investigated. During solar collector operation, natural convection of 425 cubic feet per minute has been measured.

The Kliewer family has identified the following problems after two-and-a-half years of living in and with their house:

- The floor in the lower, main living area is sometimes too cold in the winter. Kliewer said that insulation under the floor should have been installed.
- The Insulbead expanded polystyrene rigid-board insulation probably should not have been used, since it is not entirely impervious to moisture. Wet insulation loses some of its effectiveness. Recent monitoring suggests that the winter heat storage in the concrete roof is not quite what it was during the first year of operation and wet insulation is a suspected cause. Extruded polystyrene (blue Styrofoam), which handles moisture better, would have been a better choice.
- There have been problems with condensation in the collector.
- Initially, the exposed edge of the concrete roof was not insulated. This produced additional heat loss in winter or heat gain

in summer. This has since been remedied.

- The stone chimney presented similar problems. It should have been built with a thermal break of insulating cement incorporated.
- Reflectors, added to the collectors, were unstable in wind and they were removed.

COSTS AND BENEFITS

The total 2,650-square-foot house cost about $40 per square foot, excluding the lot. No attempt as been made to establish the cost-effectiveness of the added investment due to the earth-sheltered and passive-solar construction features, according to a September, 1983 interview. Besides reduced heating and cooling costs, the house has been very comfortable to live in and shares other benefits with underground living in general.

FOLLOWUP INFORMATION

The building contractor for the home was T.W. Patterson Construction Company of Siloam Springs, and the builders may be reached at 524-3291.

The structural engineer and architect who drew blueprints from Kliewer's design ideas was Kent Davis, of John Brown University at Siloam Springs.

A book, available from Tim Kliewer for $5, called *A Home For All Seasons* describes the house in great detail. Blueprints are also available.

An article about the house appeared in the October 1982 issue of *Popular Science*.

Jeff Laur Built His Envelope Home and Cools It With a Geothermal Well

Jeff Laur
P.O. Box 672
Harrison, Arkansas 72601
Telephone: 741-8376
Government Grant: None

Thermal Envelope Home of a Harrison Architect Has Solar Features That Affect the Home All Year

BACKGROUND

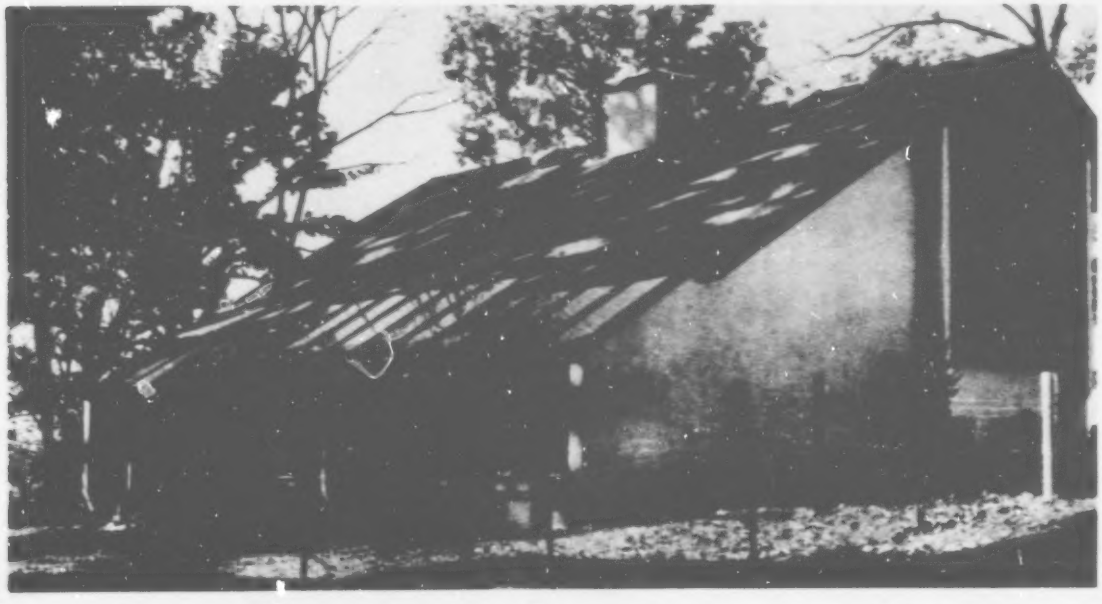
The Laur home has 2,000 square feet, which includes a 400-square-foot solar greenhouse. The greenhouse, which has ¾-inch slots in its floor, sends solar-heated air up into the double-roof envelope. Small windows on the cold north wall help this air to sink down the double wall below the house, into the gravel-filled crawl space.

After depositing any remaining heat there, the air then returns through the floor slots to the greenhouse, and the cycle begins again.

Besides charging the heating envelope, the greenhouse is the location of 64 square feet of solar collector for water heating. The collector was built on the site as the house went up. The water-heater, behind 600 square feet of double glazing, never freezes.

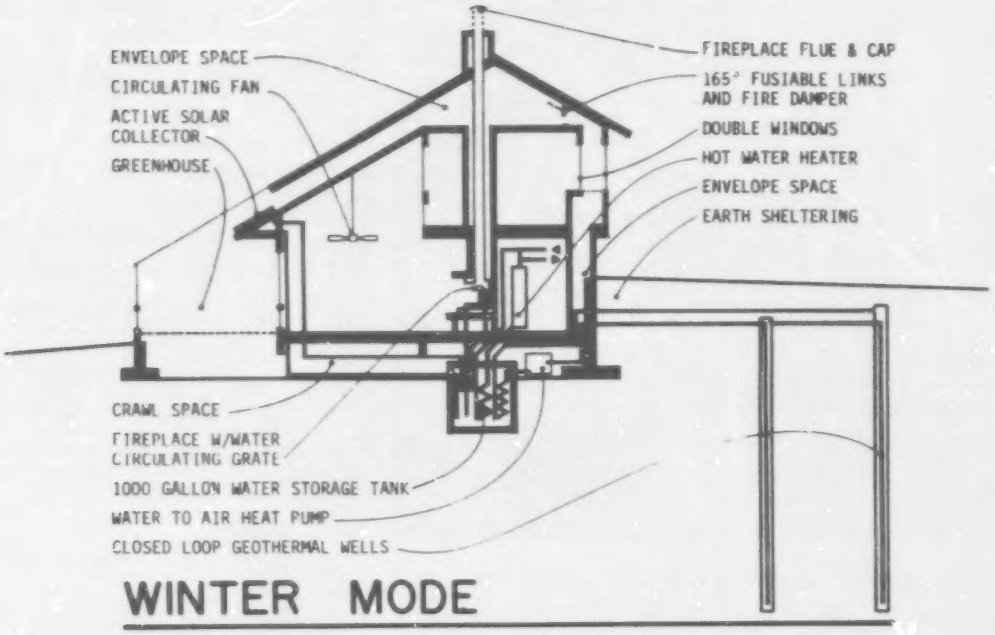
The collector employs an EPDM plastic absorber mat, and because of its non-freezing location, water is the heat-transfer fluid. A 1,000-gallon concrete tank is charged by both the solar collector and a water-circulating grate inside a fireplace. Laur located the tank in the crawl space. The tank is used both to preheat water and help heat the house.

For summer cooling, two series-connected geothermal wells provide an earth-cooling equivalent of three tons of cooling capacity.

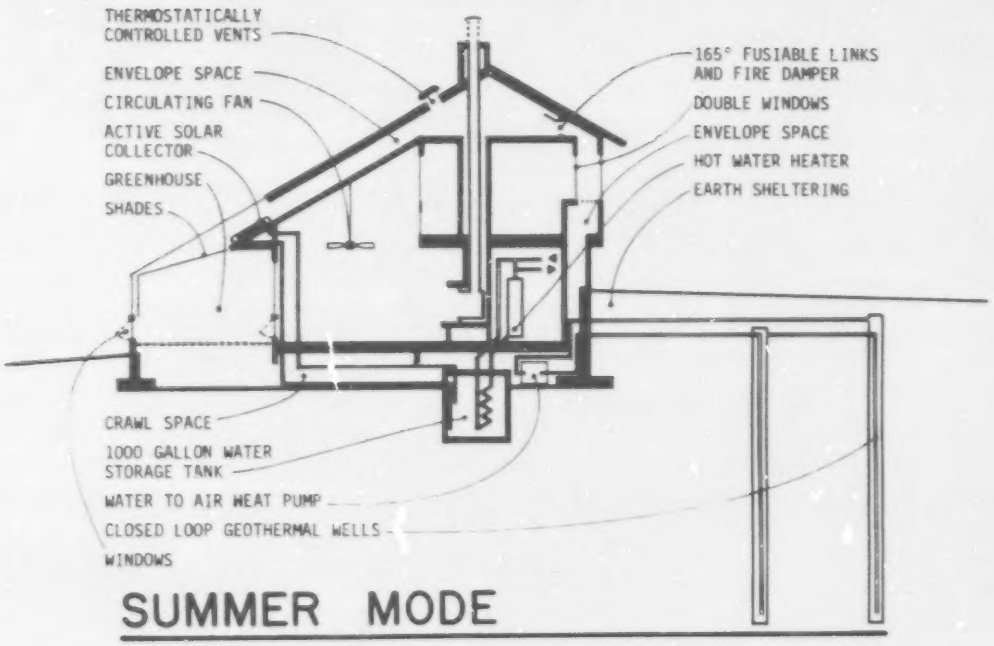


Greenhouse at the rear of the Laur home receives summer shade, to help control energy bills, at the same time its placement will admit welcome winter sunlight.

LAUR ENVELOPE HOUSE ___ N



WINTER MODE



SUMMER MODE

Jeff Laur shows off the greenhouse of his Harrison home; gaps in the wooden floor are part of the air-circulation system.

The wells are 130 feet deep. A water-to-air heat pump is coupled to the geothermal well.

The massively-insulated home employs air-lock entrances and has no east or west windows. It's earth-bermed on the north and Laur employs a summer shade curtain and deciduous trees to keep sunshine out of the greenhouse.

Laur has installed elaborate monitoring equipment inside the house to evaluate its operation better.

PERFORMANCE AND OPERATING HISTORY

Both the envelope heating and the geothermal-well cooling cycles perform about as expected according to Laur. Overall he has been pleased with the home's operation and comfort. The solar hot-water system, however, has not functioned well. This is because the ratio of storage to collector is much too high.

COSTS AND BENEFITS

The house cost approximately $82,000; the energy-saving features added 10 to 15 percent to the cost. In two-and-a-half years of living in the house, Jeff and Sharon Laur's average monthly utility bill for this all-electric home has been $51.

The low has been $35 and the high has been $78.

FOLLOWUP INFORMATION

A slide program, *Building a Solar Envelope Home*, which documents the home's construction, is available at the North Arkansas Community College Library at Harrison.

North Little Rock House by Jim Mercado Features Prize-winning Solar Home Design

Jim Mercado
Sunspace Design
12718 Valleywood Drive
Little Rock, Arkansas 72211
Telephone: 225-3994
Government Grant: None
A Little Rock Architect Built a Prize-winning Solar Home on a South Slope

BACKGROUND

Jim Mercado, a Little Rock architect, built a 1,508-square-foot solar home whose features won him $750 in the 1981 Solar Design Competition sponsored by the Arkansas Energy Office and the Arkansas Housing Development Agency. Permanent financing at 9 percent was guaranteed for the design.

The three-bedroom home has an unusual "sunspace", which has 192 square feet of double glazing and a blackened masonry heat-storage wall that is 12 inches thick. The space has supply-air and return-air ducts located to achieve thermosiphoning.

In addition, there are 72 square feet of direct-gain windows along the upper south wall.

An integrated fireplace system, with separate ducts and blower units for each room and for outside combustion air, and a two-ton electric heat pump system provide additional heating.

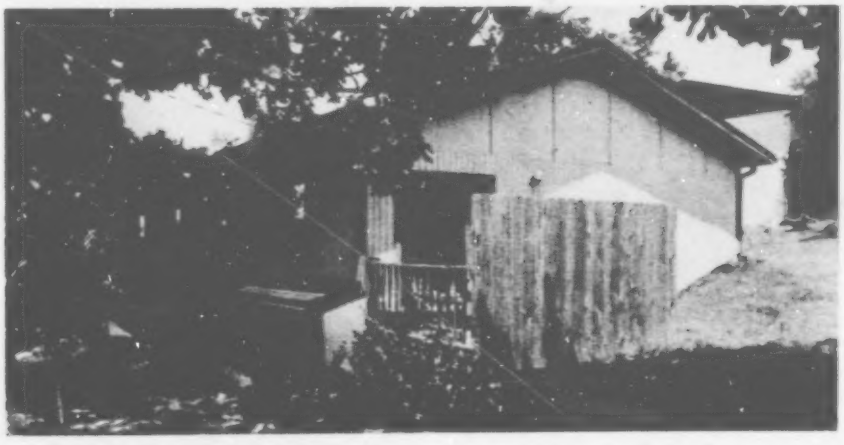
Earth tempering along the north wall, lots of thermal mass, a three-foot south wall overhang, and continuous soffit and gable vents are passive cooling features. The home is well insulated.

An active solar system — a closed-loop heat-exchange system with two Solar King™ collectors — provides hot water.

This all-electric home sold for $62,500, which included the lot. During the first year of occupancy — by one person — the largest monthly electric bill was $40.

FOLLOWUP INFORMATION

For a look at this design, consult *Arkansas Passive Solar Home Competition Regional Design Criteria*, which is available from the Arkansas Energy Office.



The prize-winning design for this North Little Rock home provides summer shade to help control energy bills as well as a bank of south-facing windows to get winter sun.

Physician at Harrison Put Solar Heating System in His New Office

Dr. Sam Scroggins
1002 North Spring Street
Harrison, Arkansas 72601
Telephone: 741-6373
Government Grant: None
Both Passive and Active Solar Systems Serve the Needs of Dr. Sam Scroggins at Harrison.

BUILDING DESIGN AND ENERGY CONCERNS

The new, massively-insulated medical complex of Dr. Sam Scroggins of Harrison employs both passive and active solar-heating systems. The office has 3,200 square feet.

A 220-square-foot double-glazed selective surface Trombe wall and 110 square feet of direct-gain windows provide the passive heat.

Active heating comes from 256 square feet of site-built solar air-heaters, which use Heliolite low-iron glass and corrugated metal absorber plate.

A thermostatically-controlled blower moves hot air at the rate of 750 cubic feet per minute, either directly into the building or into heat storage.

The storage is provided by 320 gallons of water, stored in one-gallon metal cans.

The building's walls are insulated to R-28, the ceiling to R-39 and the foundation perimeter to R-10. Reflective building foil was employed under roof sheathing to cut solar gain in summer.

Since the building is unoccupied weekends and at night, a timer-controlled thermostat sets back the temperature to maintain the building at different levels depending on the time of day, and whether people are present.

It's estimated that during the heating season this will lead to a 27 percent heating-load reduction.

A Trombe wall, direct-gain windows and solar air-heaters help heat the office of Dr. Sam Scroggins in Harrison.

PERFORMANCE AND OPERATING HISTORY

As these facilities have only been occupied since August 1983, little performance data is available.

The 586 square feet of solar collection area is expected to meet 50 to 60 percent of the annual heating load, which has been reduced because of the energy-conservation measures.

Average monthly heating bills for December and January are expected to be around $40. That assumes natural gas costs 45 cents per therm.

Heat in the worst month of the winter of 1983-84 cost $48 — with an incomplete system. Only 40 percent of the air-heater collector system was then in operation.

The building architect was D. Evans of Fort Smith, Arkansas. The solar consultants for the project were Stephen Cook of Jasper, Arkansas and Ron Hughes of Mountain Home, Arkansas.

4 Wind and Photovoltaics

Country Homes in Arkansas Benefit from Wind and Photovoltaic Systems

Photovoltaics and wind-electric systems represent technologies that are not for everyone.

Given their current high cost, photovoltaics (PVs) are cost-effective only for remote installations where bringing in power lines would be prohibitively expensive, and for certain specialized applications.

Wind generators will make economic sense only for Arkansans with a good, windy site and a place to install a tower.

Important numbers in using these technologies are $2 per watt solar cell cost and 10 miles an hour average windspeed. While earlier goals appear unrealistic, in terms of bringing down the price of photovoltaic cells, still, photovoltaic prices continue to drop. In early 1984, a price per watt of $7.25 was quoted for a 35-watt module purchase, with a minimum order of four. Another company was offering new modules of a discontinued line for $5 per watt while the supply lasted.

As photovoltaic power gets cheaper, more uses open up. The point at which the price becomes low enough for widespread usage is uncertain. That figure is thought to be $2 per watt, although there is much disagreement.

While small wind generator prices are unlikely to decline much, their reliability should improve. In contrast with commercial photovoltaic panels, which are highly reliable and should provide at least 15 to 20 years of trouble-free service, some wind generators are plagued with difficulties.

Photovoltaic power currently is employed at perhaps 75 installations throughout the state and windpower at about 60. Use of both is expected to increase in the future; in the case of photovoltaics, the growth could be explosive.

So far, one company has been responsible for two-thirds of the state's wind installations and that's Randall Richardson's Custom Towers of Harrison.

Many of the decisions that need to be made in planning a system are the same for wind systems and photovoltaics alike. Consider these decisions:

1. Should the generator equipment be purchased or built?

It is possible to assemble a photovoltaic panel for individual commercial solar cells. The experience of Dr. Richard Komp is useful here.

As for wind, building a wind generator is not difficult but building a reliable one is. The system created by Harold Matthews detailed problems to be faced.

Plans are available for home-built wind generators. Check *Wind Power Digest* ads.

Purchasing commercial solar cell modules will not be as risky as, or need as much study as, buying a commercial wind machine. Many such photovoltaic panels have good warranties and excellent performance records.

Current industry leaders are ARCO and Solarex.

In selecting a commercial wind generator, remember that many such units have undergone testing at Rocky Flats Small Wind Systems Test Center in Colorado, and you should look up their ratings at public libraries that have government documents.

2. Should battery storage or a utility tie-in system be employed?

There is Arkansas experience in both methods with wind generators, although the large installation at Mississippi County Community College in Blytheville is the state's only photovoltaic/utility tie-in system.

3. Should the system use 12 volt or 120 volt direct current or 120 volt alternating current appliances?

Steve and Laurie Cook dealt with this aspect, as did Dennis Krejci and Richard and Darlene Shrum. Their experiences are related in the following reports.

4. How far away from the point of end use can the generator be?

Steve Cook's project approached the limit-

ing distance for a 12 volt installation.

5. In battery storage systems, should a back-up generator be employed?

Steve Cook's home has none; the other installations do. Cook's work and that of Krejci document PV systems combined with wind equipment. With this approach, backup or auxiliary power may not be necessary during the summertime wind lulls or the wintertime overcasts.

6. How large should the generator be?

The expected electrical load needs to be carefully assessed. Work at North Arkansas Community College is useful on this question. Their records offer computer-derived, month by month, estimated output figures for a Northwest Arkansas photovoltaic array.

The figures are for a 660-watt array, but by scaling these numbers up or down some idea of performance for different-sized Arkansas photovoltaic arrays might be obtained.

The actual wind generator site is critical in determining power to be expected. The Fayetteville Housing Authority work is an instructive example in poor siting. The result was output far below expectations.

Cook's project is instructive in that it shows what turbulence and high winds can do.

Neither of these wind machines is still functioning.

Wind generators are at good sites at Krejci's home and at Shrum's home and these are still operating.

To assure yourself of the best-planned wind system, spend at least three months gathering wind-speed data at the intended site with a recording anemometer.

Readings should be taken at a height equivalent to that of the proposed wind machine.

Wind systems differ from photovoltaic arrays in maintenance needs and in the use of a tower. Tower height is an important factor in actual wind-generator output. Equally important is having a safe tower instaliation — for doing maintenance.

One must choose between a freestanding tower such as Richard Shrum erected, and guyed towers, which was the type selected by the others listed here.

Installing the tower can be quite a job for the novice, so it should not be undertaken without careful consideration.

Windpower for the Homeowner is perhaps the best over-all reference on installing and operating a wind machine. The author, Donald Marier et al, urges potential urban users to investigate local regulations and check with neighbors.

The Enertech wind machine erected by Jim Keel at Harrison unfortunately was installed near a property line. The unit proved so noisy on startup and shutdown that neighbors successfully demanded it be shut down at night.

This greatly reduced output from the machine, since it sits idle roughly one-third of the time.

A photovoltaic array installation will not present nearly as many difficulties. For small arrays, seasonally changing the tilt angle can lead to increased output; a computer study of this was done at the North Arkansas Community College at Harrison.

Employing fixed reflectors or using a tracker can also increase output.

Other possibilities include employing concentrators and even capturing some of the waste heat from the array.

Richard Shrum Uses Windpower at His Boston Mountain Home near Pelsor

Richard and Darlene Shrum
Route 1, Box 55
Pelsor, Arkansas 72056
Telephone: Unlisted
Government Grant: None
A Four-kilowatt Wind Generator Powers a Home Too Far From Power Lines.

BACKGROUND

When the Shrums got word from their local utility company, Carroll Electric Cooperative, that it would cost $6,500 to bring electric power lines one mile to their home, they began to look for an alternative.

Given their Boston Mountain ridgetop location, it wasn't long before they began to consider a wind-electric system seriously.

Richard Shrum and his neighbors join forces to erect the Dakota Sun & Wind wind machine.

The Shrum family joined forces with another family nearby, and together they purchased two Dakota Sun and Wind four-kilowatt wind machines, which saved $1,000 on their generator.

A trip to Iowa led to the purchase of a 60-foot tower, once used for a Kansas water-pumping windmill.

Early in 1981, after purchasing a battery bank and getting help from Randall Richardson of Harrison, a wind-generator installer, the Shrums had their own electricity.

The 550-pound generator was modeled after the old, reliable Jacobs design. Unfortunately, the makers of the Dakota machine encountered financial difficulties and their generators are no longer made.

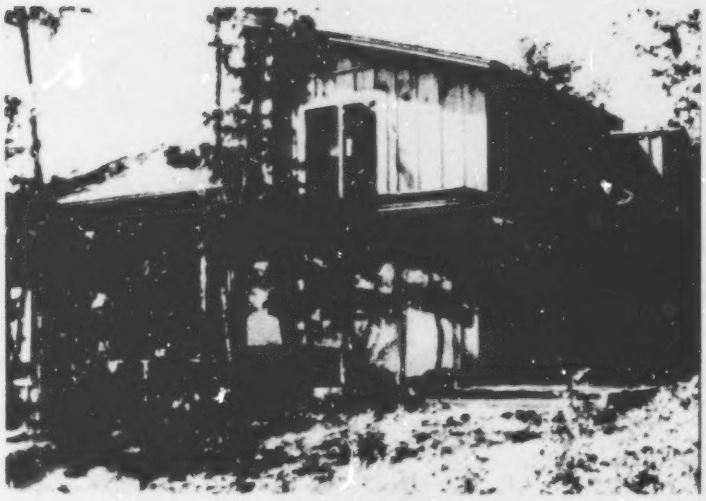
BUILDING DESCRIPTION AND ENERGY CONCERNS

The well-insulated Shrum house is a passive solar design, the work of Fayetteville architect Albert Skiles. The design provides 2,000 square feet of space. Liquified-petroleum gas is the fuel for cooking, refrigeration and water heating.

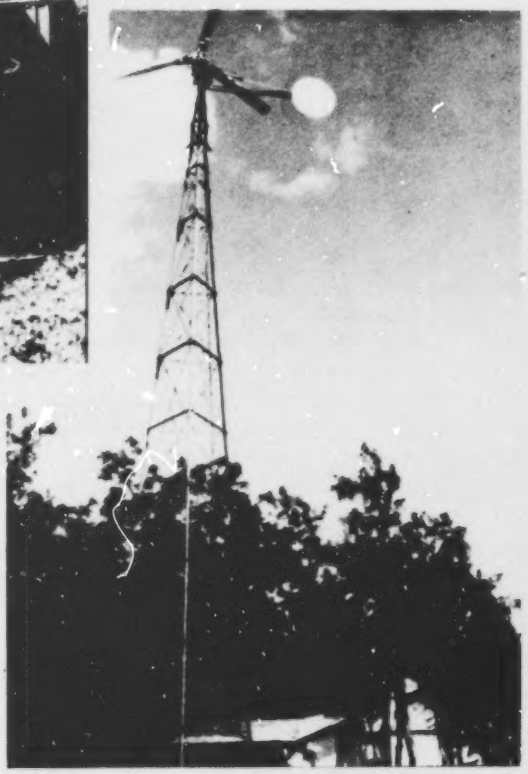
The wind tower sits about 200 feet away, with the battery shed at its base. The tower site is on a finger of flat ridgetop at a 2,100-foot elevation with valleys on the north and south sides.

POWER GENERATION

The four-kilowatt direct-drive Dakota machine has a 14-foot-diameter, three-blade rotor.



The wind machine tower and battery shed (below) are located 200 feet from the Shrum's passive solar home (left).



It starts charging in a nine-mile-per-hour wind, and delivers its rated power at 140 volts direct current in a 27-mile-an-hour wind. The tower is a freestanding one, 60 feet high.

ELECTRICAL STORAGE AND BACKUP

Twenty 6-volt Astrolite golf-cart batteries hooked together in series supply approximately 20 kilowatt-hours of storage at 120 volts direct current. There are two gasoline generators — 4,000 and 2,000-watt units — for backup.

ELECTRICAL LOAD DESCRIPTION

The lights run off the 120-volt direct current battery bank. Many of the other appliances, including a large stereo system, are powered by a 3,000-watt inverter. The vacuum cleaner, blender, food mixer, sewing machine, and virtually all shop tools (saws, drills, etc.) run well on 120-volt direct-current power.

PERFORMANCE AND OPERATING HISTORY

The wind generator has performed admirably in two-and-a-half years of service. The generator brushes show virtually no wear. A lightning strike did destroy a diode, but it has been replaced and the whole unit now is protected against lightning.

The Shrums had some frustrating troubles with their original inverter, a new and supposedly advanced product. It has since been replaced.

The Shrum wind site appears to be a good one, although no monitoring of electrical production or wind speeds has been done. In an 11-mile-an-hour average windspeed location, the Dakota machine **should** produce an average 300 kilowatt-hours per month. There are summertime calm spells, but with the Shrums' lifestyle, which keeps them at their Eureka Springs craft shop during the busy summer months, this hasn't been a real problem.

The backup gasoline generators have been used sparingly. In planned system modifications, the Number 6 copper wire linking house

and battery shed will be replaced with heavier wire, and additional battery capacity will be added.

COSTS AND BENEFITS

The Shrum's major expenditures have been:

Wind Generator	$3,000
Tower	500
Batteries	1,200
Inverter	1,700

The generator and tower were real bargains and normally would cost considerably more. There have been additional miscellaneous expenses.

Assuming an $8,000 total system cost, less a 40 percent federal energy—tax credit, means a total investment of $4,800. The **assumed** 300 kilowatt-hours per month, if it is pegged to utility-company prices, is worth $360 a year, at the current cost of about 10 cents per kilowatt-hour. Dividing these two figures (4,800 by 360) for a simple payback calculation, yields 13.33 years.

Jacobs-style wind machines typically provide 20 to 30 years of trouble-free service, with no major repairs, so the investment should turn out to be a sound one.

That investment is even more attractive considering the capital cost of running a power line to their home. For the Shrums, given their remote location, the choice was between a $6,500 capital cost plus $360 per year operating cost (at current rates) and a $4,800 capital cost plus essentially no operating cost other than occasional maintenance.

COMPARISON OF COSTS

Capital Cost

Homemade electricity	$ 8,000
40 percent federal energy tax credit	- 3,200
	$ 4,800
Electric utility	$ 6,500

Operating Cost Annually

Electric utility	$ 360
Homemade electricity	-0-

For remote applications, wind-electric and/or photovoltaic installations can have very short paybacks, when the cost of a utility hookup is considered.

Dennis Krejci Installed Two Wind Generators at his Mountain-top Home near Harrison

Dennis Krejci
Route 3
Harrison, Arkansas 72601
Telephone: 743-3149
Government Grant: None

At This Independent Homestead, Wind and Photovoltaics Power The Electrical System, and Wood and Solar Energy Provide Hot Water and Space Heating.

BACKGROUND

The Krejci family suffered quite a setback four years ago when their house burned down.

Long interested in alternate energy, Krejci rebuilt, emphasizing energy efficiency. He also turned to the wind for his electricity, installing two 200-watt Winco generators and a 12-volt battery bank.

Though he had service from Arkansas Power and Light Company, and a gasoline backup generator, Krejci found that his wind generators performed well at his site. He decided to use all they produced.

He began converting many shop tools to run on 12-volt direct current, and acquiring other 12-volt appliances.

Although his hilltop site is a good one for wind, Krejci wanted some solar electricity during the six weeks or so of summertime calm. About a year ago, he traded one of his Winco generators for some used ARCO photovoltaic panels.

He also acquired a 1,000-watt Bergey wind machine, which produces alternating-current power, and ties in with the utility company, and a bigger, 450-watt Winco.

He acquired some **good** "used" batteries, which replaced automotive batteries. As it turned out, the second set was hardly used at all.

Today, the Krejci family's standard of living is high — their swimming pool pump is a big user of electricity!

Their energy bills are low.

Krejci is not finished, however. His latest projects are adding a 10 × 14-foot solar greenhouse to the south side of the house, and building a three-blade rotor for the 450 watt Winco.

Construction of two wind machines marked the beginning of the Krejci's renewable lifestyle.

BUILDING DESCRIPTION AND ENERGY CONCERNS

The 1,200-square-foot, three-bedroom house is of wood frame construction. It has six inches of fiberglass in the walls, 25 inches of blown-in fiberglass in the ceiling and two inches of Styrofoam below the concrete floor.

A double-glazed opening in the attic houses a homemade 4 × 8-foot flat-plate collector and a 30-gallon batch water heater.

The flat-plate collector contains 200 feet of coiled copper tubing and, hooked in series

with the 30-gallon tank, these function as preheaters for the hot water.

In fact, Krejci has three hot-water resources — solar, wood or LP gas. Cooking is on an LP gas range, and a wood stove heats the house.

RENEWABLE ELECTRICITY GENERATION

The Krejci family uses this system:

A 1,000-watt Bergey alternating-current wind generator on a 100-foot tower; a 450 watt Winco 12-volt generator on a 90-foot tower; and 165 watts provided by eleven 15-watt ARCO used photovoltaic modules flush-mounted on a roof with a 3 in 12 pitch (15 degree angle).

The panels are early models.

The Bergey generator is hooked into the power-company meter and runs it backwards when supplying alternating current to the house. The Winco employs a voltage regulator; the solar system is unregulated.

Two inverters, a Winco 800-watt unit and a Tripplite 400-watt device, convert 12-volt battery power to 120-volt alternating current power. The wind generating systems were installed with the aid of Custom Towers of Harrison, Randall Richardson's firm.

ELECTRICAL STORAGE

Twenty-four 6-volt C&D 180 amp-hour batteries hooked together in series and parallel provide 2,160 amp-hours (at 12 volts) of storage capacity.

ELECTRICAL LOAD

The system powers nearly all major electrical appliances, including a refrigerator, washer, dryer, freezer, etc. There is no electric hot water, range, or air-conditioning.

Many of these run on 12 volts, such as the refrigerator, lighting, etc., although with the Bergey alternating current now available, many shop tools now run on alternating current.

ELECTRICAL BACKUP

Electric utility service is available. The gasoline generator had not been needed to charge the batteries for two years, so it was sold.

PERFORMANCE AND OPERATING HISTORY

Dennis Krejci reports that he never discharges his battery bank more than 50 percent of rated capacity, and that he always maintains at least 12.1 or so volts. The reason is that he has plenty of power!

From some monitoring, which is mostly watching wind-machine revolutions per minute, he estimates his annual average windspeed at 10½ miles an hour — ranging from summertime lows of 3 miles an hour up to 14 to 16 miles an hour in the spring.

Krejci has been quite pleased with the Bergey unit. He notes that it generates 600 watts of power in light winds and peaks at 1,650 watts, despite its rating of 1,000 watts.

His former 200-watt Winco, he'll tell you, effortlessly and continually provided 15 to 20 amps output. He learned to "fine-tune" this machine for maximum performance. He concluded that readjusting the tail vane so that it sits squarely in line with the generator is important for good performance.

Krejci said that he was not sure the Winco 450 actually outperforms the smaller, Winco 200, as one would expect. That led to his attempts at replacing the two-blade rotor on his first machine with a three-blade one.

Krejci said that he was thankful for the boost the photovoltaics give his batteries during the calm summer periods. He keeps their orientation fixed at the low roof angle to maximize summer production, and has experimented with reflectors to increase their output.

COSTS AND BENEFITS

Krejci has $6,000 invested in his renewable electrical-generation and solar water-heating system. However, he has connections in this field, and has done some trading and building that have kept that figure low.

Someone wishing to duplicate his system

could easily spend twice that amount. His monthly purchases of 1,200 to 1,500 kilowatt-hours have, with the advent of the renewable systems, now dropped to only 250 to 350 kilowatt-hours per month for household use.

Besides his own electricity generation, a change of lifestyle and energy-efficient appliances have played a key role.

Looking at total energy usage, the Krejci family estimates that without their renewable energy measures, they would spend $2,800 per year on energy.

As it is, they spend around $640 annually — on electricity bills, LP gas, and firewood purchases. Dividing the estimated annual savings — over $2,000 — into the $6,000 investment shows a payback of three years, which says something about the benefits of their renewable lifestyle.

Wind and Sun Power Served the Country Home of Steve and Laurie Cook near Jasper

Steve and Laurie Cook
Gum Springs Road
Jasper, Arkansas 72641
Telephone: 446-2211
Government Grant: $2,550
Photovoltaics and Wind Powered a Low-cost Passive Solar Home in the Ozarks.

BACKGROUND

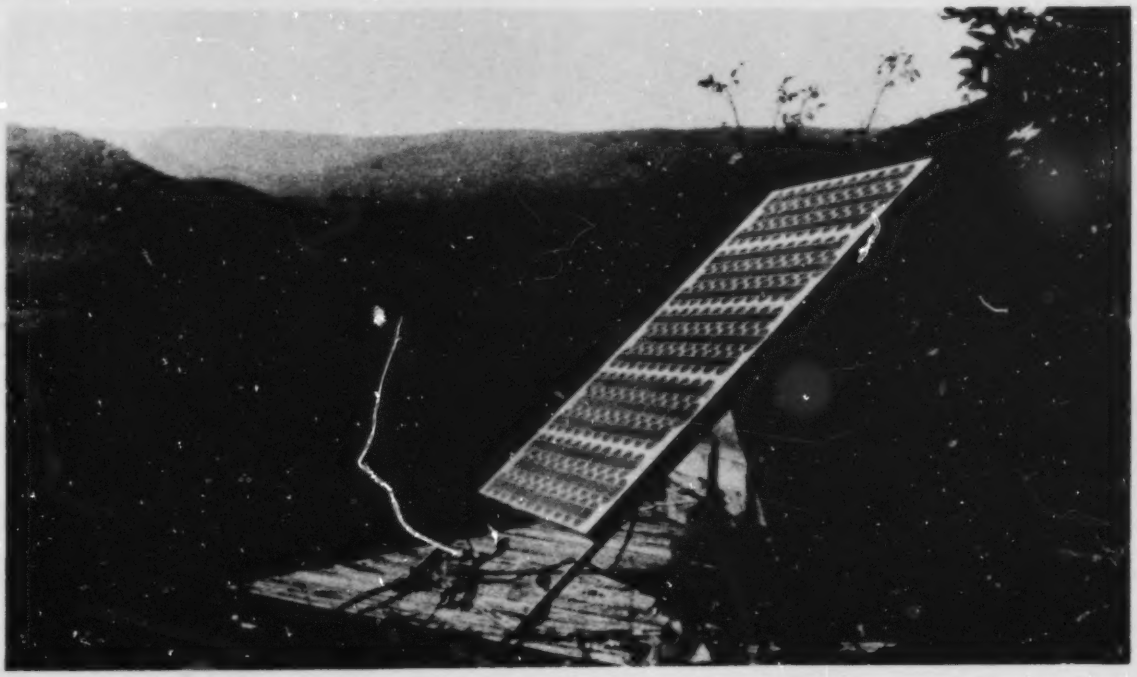
For three years the Cooks lived without electricity. In July 1980, 100 watts of photovoltaics were installed, followed shortly by a 200-watt wind generator.

With highly energy-efficient 12 volt appliances and meager needs, the Cooks have lived for nearly four years on an average of 15 to 20 kilowatt-hours per month of electricity.

While their system configuration has recently changed — they now have more photovoltaics and no wind generator — they still have only renewable electricity (no gasoline backup).

Although the Cook's two-and-a-half year experience with wind electricity ended in March 1983, when high wind caused equipment damage, Cook said that he was convinced that his decision to use wind helped bring the wind industry to Arkansas.

The decision was made easier with the support of a $2,550 grant from the Arkansas Energy Office. In the spring of 1980, Cook sounded out Randall Richardson of Harrison, a television-antenna tower builder, about adapting and installing a tower for a wind generator.



Photovoltaics are ideal for isolated spots such as this one at the Cook's home near Jasper.

This was the beginning of a new line of business for Richardson, who since then has installed the majority of Arkansas' wind systems, having perfected his techniques through experience.

BUILDING DESCRIPTION AND ENERGY CONCERNS

The 1,000-square-foot Cook house is passively heated with 280 square feet of single glazing on the south wall. The house has been built on and around a huge natural rock outcropping, in a low-cost way to earth-temper the house and provide thermal mass.

The house is insulated to R-20 in the walls, R-30 in the roof, has double-glazed east and west windows, and employs movable insulation on the south glazing. Unique ventilation, earth-tempering, an overhang and a forested location are summer cooling features.

Laurie Cook raises the movable insulation on the south glazing to admit the sun's heat.

A wood stove is used for heating and a combination wood/gas stove for cooking and hot water. Water comes from a gravity-feed spring/storage tank combination.

RENEWABLE ELECTRICAL GENERATION

The system prior to March, 1983, consisted of: 1) a 200-watt Winco wind machine on a 100-foot guyed tower — four hundred feet of aluminum wire transmitted 12-volt direct current to the house; and 2) three ARCO ASI 16-2000 photovoltaic modules, providing 100 watts total.

After March 1983, two ARCO panels were added and the five photovoltaic modules were moved to a sunnier location. The wind generator is beyond repair.

ELECTRICAL STORAGE AND BACKUP

Both wind generator and photovoltaic panels charged the same battery bank. Prior to January 1982, six two-volt C&D 420 amp-hour used batteries were employed — hooked in series to give 12 volts.

Since then, six two-volt C&D 500 amp-hour almost-new batteries have been used. There is no backup generator.

ELECTRICAL LOAD DESCRIPTION

These appliances use 12-volt direct current:

- Five quartz-iodine lights, which draw 20 watts each (from J. C. Whitney Company);
- Five "air-craft type" incandescent directional lights, which draw 12 watts each;
- A Koolatron refrigerator, (1.7 cubic feet), which averages 24 watts when the temperature is 70 degrees;
- A Midland AC/DC black-and-white 12-inch television, which draws 16 watts maximum;
- A car stereo cassette/AM-FM radio, which draws 20 watts maximum;
- An auto vacuum cleaner, which draws 108 watts;
- A power tool set, including 12-volt drill, circular saw and sander, each of which typically draws 15 amps (from I.D. Rathelby, Fountain Valley, California);
- A kitchen blender (from Independent Energy Systems, Nevada City, California), which draws 40 watts maximum; and
- An 8-inch, 600 cubic-feet-per-minute circulating fan, which draws 14 watts.

A 250-watt frequency-controlled Tripplite inverter is used to power a microcomputer and stereo turntable.

ELECTRICAL CONSUMPTION In KILOWATT-HOURS

Month	Overhead Lights	Directional Lights	TV	Refrig-erator	Vacuum	Radio/ Tape	TOTAL
DEC 1980	7.4	1.1	3.0	0.7	0.2	0.3	12.7
JAN 1981	7.4	1.1	3.0	0.4	0.2	0.3	12.4
FEB 1981	5.6	0.7	2.2	1.3	0.6	0.2	10.5
MAR 1981	6.2	0.7	2.5	3.0	0.9	0.3	13.6
						AVERAGE:	12.3

PERFORMANCE AND OPERATING HISTORY

The Winco wind machine experienced difficulties because of excessive turbulence at the mountainside elevation where it operated. It was 1,900 feet above sea level at the ground elevation; then the tower added another 100 feet.

It was above all obstructions for two miles to the west but was within a couple hundred feet of obstructions to the east, where trees and the mountain top (elevation 2,075 feet) hindered operation.

With the winds coming predominantly from the west, the site had plenty of wind but excessive turbulence.

The problems experienced included:

The power-robbing turbulence, which at times reduced electrical production.

The Winco voltage regulator, which sensed the solar cell's battery-charging voltage (on sunny days) and often cut out the wind generator's output — even though the batteries were not really in danger of being overcharged.

The regulator was finally taken off — it was wasting power! — and battery voltage was regulated through appliance use if necessary. Laurie Cook sometimes used the vacuum cleaner during high wind periods!

The leading edge sheet-metal flap on the blades was eventually torn off.

Grease and dirt got on the generator's collector ring copper brushes and the poor contact reduced output.

Unfortunately, winds estimated at 60 to 80 miles an hour slammed into the installation in March, 1983 and did irreparable damage. The upper tower section was badly twisted, the generator thrown to the ground and the blades destroyed. The tower, being the first Custom Towers wind installation, was not built from the very-heavy-duty steel angle-iron now being employed.

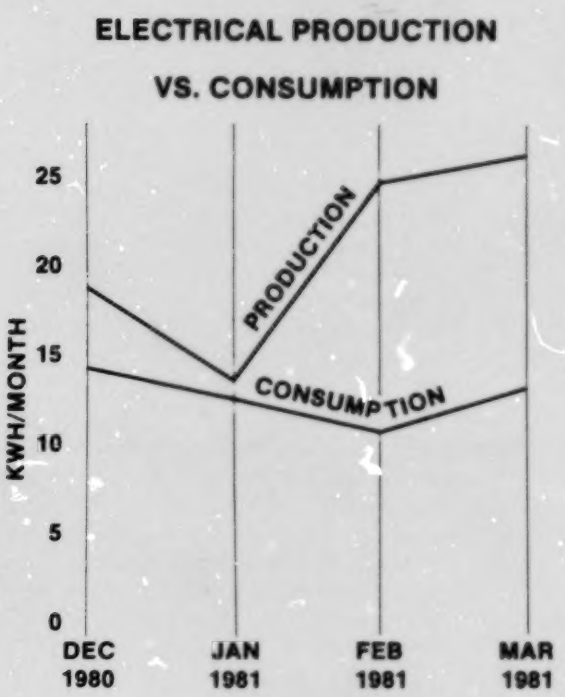
Cook concluded that the site is not appropriate for a wind machine. Before installation, spot monitoring had indicated promising wind speeds but Cook did not look for turbulence.

This could have been checked by tying a long ribbon streamer to a pole or mast and watching for its subsequent even or uneven movement in the wind.

The photovoltaics have performed up to expectations and there have been no problems. After nearly four years of operation, there has been no apparent reduction in outputs. Periodically, two bolts were loosened and the panel tilt-angle was adjusted to optimize output.

MONITORING

A Natural Power DC amp-hour meter recorded combined wind and solar electricity production from December, 1980 through March, 1981.



During the above monitoring period the voltage regulator was employed, and output was reduced.

A 10 percent transmission loss occurred in the wind generator operation because of the distance between it and the house. The photovoltaics suffered a 15 percent reduced output from shading by obstructions.

The average 20 kilowatt-hours per month production is estimated to be only 60 percent of what the system would have produced without these problems.

The 200-watt Winco alone should provide 20 kilowatt-hours per month at a 10-miles-an-hour average windspeed site.

BATTERIES

The used batteries, 15 years old when scrapped by the phone company and supposedly with many good years remaining, were used one-and-a-half years before they were replaced. They had an effective storage capacity of only 20 percent or so of their new 425 amp-hour rating and they clearly were wasting energy.

(As batteries age their internal resistance increases and electricity is increasingly wasted in so-called "I squared R losses," being dissipated as heat.)

The inadequacy of these batteries was particularly evident when the new batteries were installed. The new battery bank, storing six kilowatt-hours of electricity, can, by itself, run the house for up to 10 days when fully charged.

The Cook family, having no backup generator, at times discharge these batteries to a lower level than they would prefer. After a few days of cloudy weather, they curtail appliance use when battery voltage drops below 12.0 volts. Below 11.2 volts, the Cooks will not use the batteries, in an effort to prevent damage to them.

So far this has not been necessary. Previously, during cloudy spells, the Cooks relied upon wind electricity, Now, without the wind machine, the cloudy-day diffuse-light energy production of the solar cells, which is up to 20 percent of sunny-day output, is critical to them.

APPLIANCES

The well-insulated portable refrigerator is the Cook's biggest user of electricity in summer.

In winter, it is taken out to the unheated porch and "charged" with cold nightime temperatures.

In summer, a variable thermostat controls interior temperatures. In periods of low electricity generation, the food will be kept warmer. The unit has performed well in three-and-a-half years of constant use, except for plastic door latches, which have twice been replaced.

The high-efficiency lights deliver light equivalent to a 60-watt incandescent bulb for 20 watts of power. The Cooks say that they like the light quality, and view it as far superior to fluorescent lights; however, they disagree with claims about the long lifetime of the bulbs.

For them, the typical light bulb provides six to 10 months of use, despite the fact that they are advertised to last three times as long as incandescents! This is a problem because the replacement bulbs are expensive, and cost $3 to $4 each. Keeping these bulbs clean is important, and so is careful handling; they are quite fragile.

PASSIVE HOUSE

The cooling mode of the house works very well. Earth-tempering helps provide cool air, which is pulled through the house by a naturally-induced draft.

A roof-top false ceiling is removed in summer, exposing large peak vents where hot air can exit. During the record-setting heat wave of July, 1980, the lower levels of the house never got above 79 degrees. This was without any use of cooling fans.

In winter, an estimated 30 to 40 percent of the heating load is met by solar energy. Winter shading of the south wall by the bare branches of deciduous trees has proven to be more of a problem than expected. However, the Cooks are somewhat hesitant about cutting too many of these trees; their leaves help keep the house shaded and comfortable in the summer.

COST AND BENEFITS

The chief expenditures for the electricity generation system have been as follows:

Photovoltaics	$1,535
Wind generator	625
Wind tower	620
Transmission wire	355
Batteries	325
Inverter	150
Miscellaneous	125

The house materials cost $5,000, a figure kept low by the use of much "recycled" material.

The annual bill for energy costs is estimated to be $100 — $60 for LP gas and $40 for gas, oil and maintenance expenses for a chainsaw. The wood is readily available free; the Cooks live on 22 acres of forest badly in need of thinning.

Fayetteville Wind Energy Project Teaches Caution in Planning Future Installations

Fayetteville Housing Authority
Chad Kumpe
1 North Street
Fayetteville, Arkansas 72701
Telephone: 521-3850
Government Grant: $7,402
Wind Electric System with Utility Tie-In Was Installed Atop Building in Fayetteville.

BACKGROUND

"It didn't work."

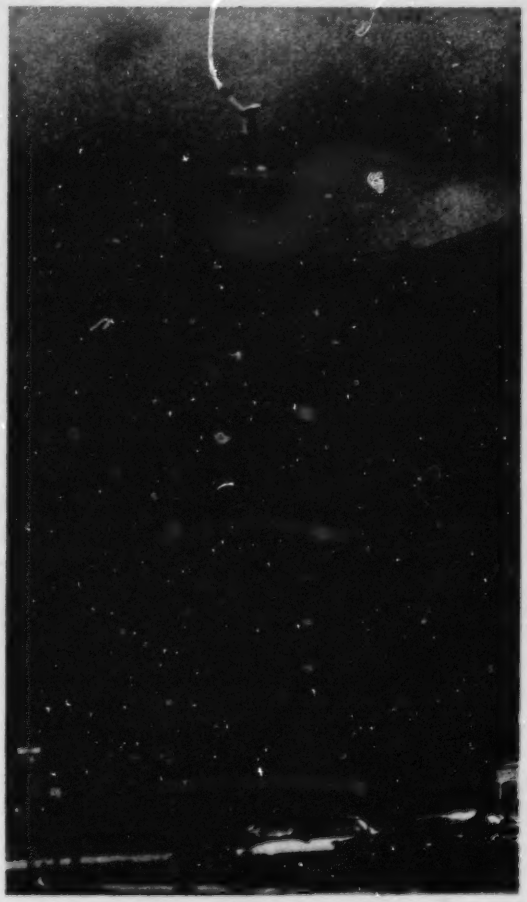
That was Chad Kumpe's evaluation of the performance of a 1,500-watt wind machine atop Hillcrest Towers in downtown Fayetteville. Kumpe, who managed the project for the Fayetteville Housing Authority, said that the unit did produce some electricity, but it never lived up to the **expectations** of the project's planners at the University of Arkansas at Fayetteville.

What should those expectations have been, given available area windspeed statistics, the specifications of the wind machine, and the site?

Sadly, no monitoring of actual windspeed at the proposed site was done. The project planners' view about the wind resource available was summarized in their application for federal funding:

> The best wind data found for the Fayetteville area were recorded in 1953 at Drake Field, the Fayetteville Municipal Airport. The annual average windspeed was recorded as 8.1 mph. Wind velocities at Hillcrest Towers should be considerably better than the ones recorded for Drake Field. Drake Field is located at an altitude of 1,200 feet while Hillcrest Towers is located at an altitude of 1,460 feet. The generator will be 162 feet above the ground level, which will put it at an altitude of 1,522 feet.

A figure is presented at that point in their report, which shows that a dramatic increase in windspeed with increasing height above the surface should be expected.



The Enertech wind machine atop Hillcrest Towers in Fayetteville provided low output and suffered some vibration.

EXPECTED PERFORMANCE OF ENERTECH 1800

CASE A

MONTH	REF WIND MPH	TOWER WIND MPH	KWH/MONTH
Jan	9.6	12.20	232.4
Feb	10.0	12.70	232.0
Mar	9.4	11.90	220.2
Apr	11.3	14.30	323.0
May	7.9	10.00	131.5
Jun	7.5	9.50	106.4
Jul	6.0	7.60	44.1
Aug	6.2	7.85	51.2
Sep	6.8	8.60	73.4
Oct	6.5	8.20	63.0
Nov	7.1	9.00	87.0
Dec	9.7	12.30	238.6
Average			150.2

Assumption: REF height of 30 feet, TOWER height of 162.5 feet, Enertech 1800 wind machine and 8.1 MPH annual average windspeed.

CASE B

MONTH	REF WIND MPH	TOWER WIND MPH	KWH/MONTH
Jan	9.6	9.0	89.0
Feb	10.0	9.3	93.6
Mar	9.4	8.7	82.0
Apr	11.3	10.5	151.3
May	7.9	7.4	38.3
Jun	7.5	7.0	28.6
Jul	6.0	5.6	7.7
Aug	6.2	5.8	9.6
Sep	6.8	6.3	16.6
Oct	6.5	6.1	13.0
Nov	7.1	6.6	21.3
Dec	9.7	9.1	92.6
Averge			53.6

Assumption: REF height of 30 feet, TOWER height of 18.5 feet, Enertech 1800 wind machine and 8.1 MPH annual average windspeed.

Note: The TOWER WIND is less than the REF WIND here because the airport anemometer (REF) height of 30 feet is higher than the 18.5 foot TOWER height.

In preparation of this article, a more detailed examination of the situation was undertaken. A computer-aided analysis brackets the range of expected performance of this wind machine at the site in question, using the specifications of the Enertech machine, reference wind speeds, and a standard profile of how wind speeds increase with height. (See accompanying figures.)

Ignoring surrounding obstructions and using the ground for reference, Case A optimistically bases calculations on a 162.5-foot tower height — the 144-foot building plus 18.5-foot tower.

Clearly, however, the Fayetteville Housing Authority building, with its broad base, presents significant obstruction to free, unimpeded wind flow. A more pessimistic assumption, as in Case B, calls the building top the reference level, thus calculating the tower effectively at only 18.5 feet high.

Computer runs, showing potential electrical output for the "optimistic" Case A and "pessimistic" Case B, are presented in accompanying figures. The actual performance should be expected to fall somewhere between these extremes. Anticipated kilowatt-hour per month production ranges from 53.6 to 150.2 when averaged over an entire year, but only from 19.0 to 78.3 when averaged over the six months from May to October.

While project planners expressed disappointment after the low output of the first months of operation, the 57 kilowatt-hour per month average obtained was well within the range of expectations identified here.

Bear in mind, however, that in an unobstructed area with 10 mph annual average windspeed, an Enertech Wind Machine can be expected to produce 240 kilowatt-hours per month, on the average.

Such a gap between design potential and performance expectations suggests rethinking the proposed site.

In this installation, the tower height is a problem; general rules of thumb call for a wind generator to be placed at about twice the height of the building itself, and never lower than 40 feet above significant obstruction.

A preliminary site analysis is useful primarily to rule out a site or to indicate whether there is reason enough to proceed with site monitoring. Most importantly — and this cannot be stressed too much — in deciding whether to install a wind machine, there is **no substitute** for actual anemometer data at the site, at the proposed height of the generator. Flag tests to indicate turbulence are also recommended.

RENEWABLE ELECTRICITY GENERATION

The Enertech horizontal axis downwind machine specifications are:

Cut-in wind speed	10 mph
Cut-cut wind speed	40 mph
Rated wind speed	22 mph
Rated power output	1.5 KW

At its new location in New Mexico, the Enertech wind machine is producing electricity at an Indian reservation.

The Enertech was installed on an 18½-feet-high, guyed tower atop a large, broad-based building 144 feet above ground level.

The Southwestern Electric Power Company (SWEPCO) provided backup for this utility tie-in system.

ELECTRICAL LOAD DESCRIPTION

The wind electricity supplemented SWEPCO power in meeting the general electrical needs of the building.

PERFORMANCE AND OPERATING HISTORY

Between May and October, 1980, an average of 57 kilowatt-hours per month was actually produced, according to monitoring. The Enertech suffered from vibration problems when winds came from the north.

Vibration suggests excessive uneveness in the wind-flow pattern and the presence of power-robbing turbulence at the site.

Due to low output, the Enertech was taken down and moved — first to another site in Fayetteville, and eventually to a site in New Mexico. At its new location, it is producing electricity at an Indian reservation.

COSTS AND BENEFITS

The entire project cost around $7,500, including $4,000 for the wind machine and around $2,000 for the tower. The chief benefit appears to be a hard lesson in how (and where) **not** to site a wind machine!

Harold Matthews Built Wind Generator From Scratch, Then Turned Instructor

Harold Matthews
Route 2, Box 252A
St. Joe, Arkansas 72675
Telephone: 427-[illegible]130
Government Grant: None
Recycled Materials Kept the Cost Low on Wind Machine He Built.

BACKGROUND

Harold Matthews built one four-kilowatt wind machine, and then presented instructions on building the device, and shared his experience with a class titled *Wind and Solar Electricity Systems* at North Arkansas Community College at Harrison. Instructors were Matthews, Randall Richardson and Stephen Cook. Forty attended.

Matthews could not afford the $8,000 a wind-electric system would cost, so he built his own — for around $1,500 and lots of hard work.

Building a reliable, durable wind machine isn't easy and Matthews still doesn't know whether he's discovered and corrected all the flaws.

However, his basic design is promising and potentially could prove to be as reliable and durable as some commercial wind machines sold today.

PROCEDURE

Building contractors usually drive the generator with a gasoline engine; Matthews planned to use the wind to turn it.

He encountered a problem: making the wind rotor blades turn the generator fast enough to produce useful amounts of electricity. Even small two-blade rotors can reach only 1,000 revolutions per minute and the General Electric generator requires at least 1,500 revolutions per minute to reach 110-volts, and 1,800 revolutions per minute to reach peak output.

The Matthews three-blade rotor would turn at most 200 revolutions per minute; that meant the transmission needed to increase its rate of rotation by nine times or so. A universal joint was used to mate the generator, which weighs 105 pounds, to the transmission, which weighs 55 pounds.

To construct the wooden blades for the rotor, Matthews used high-quality ash and did the shaping with an electric planer. As one who used to build model airplanes, Matthews said that he felt he could generate the proper

MATERIALS

- ★ General Electric four-kilowatt 120 volts alternating-current alternator, used by building contractors for portable power.
- ★ Transmission, in sealed oil bath gearbox, used to increase revolutions per minute by 8.83 times.
- ★ Universal joint (automotive type) for coupling alternator to transmission.
- ★ Three pieces 2 × 8 inches × 8 feet straight-grain ash, kiln dried.
- ★ Varnish, enamel primer.
- ★ Rotor hub built from scrap, including 6-inch and 12-inch well casings and car axles.
- ★ Three heavy-duty springs for rotor speed-governing mechanism.
- ★ Sheet metal, angle iron for tail vane assembly.
- ★ Heavy chain, pulley for rotor shutdown mechanism.
- ★ Generator turntable: pipe shaft, tapered roller bearing, metal disk, triangular plate.
- ★ Grease for rotating shaft.
- ★ Slip ring assembly: electrical brushes (from GM starter), brass inserts (from centripetal pump).

Harold Matthews began building the blades for his wind machine with high-quality ash and a knowledge of model airplanes.

aerodynamic blade contour.

If others lack such insight, then they should first plot a graph of the blade shape from standard, aerodynamically-efficient airfoils — the Clark Y is a well-known one. Make a template, and use it to generate the blade shape.

Matthews protected his blades with two coats of enamel primer and two coats of thick varnish. The leading edge of the blades was protected by stapling a thin piece of sheet metal to them.

The blades are eight feet long, weigh 23 pounds each, and when attached to the rotor hub, they make a rotor 17½ feet in diameter.

This blade assembly needs to be carefully balanced to minimize vibration. Small lead weights can be added (if needed) to one or two of the blades to obtain better balance. Matthews suspended the blade assembly and used plumb bobs to achieve adequate balance, after initially using an auto tire bubble balancer without much luck.

Then Matthews dealt with the problem of providing a way for the wind machine to govern itself in high winds, which otherwise might destroy the blades. A greased keyline path was welded onto each shaft near the center hub.

Springs normally hold the blades in but, as the blades turn faster, with increasing wind, there is more and more centrifugal force pushing them out. An engineer calculated that at 200 revolutions per minute, there was 600 pounds of outward force on those blades.

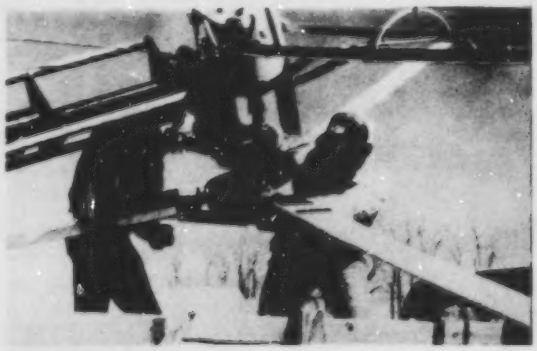
In very high winds, there is more force and springs don't supply enough tension to hold the blades to the center hub. Then they move outward along the keyline path provided and, due to the configuration of the path, change their pitch, governing the rotation.

For manual shutdown, the tail vane can be used to direct the rotor out of the wind. A heavy chain, which is hooked to the tail vane and goes through a pulley, can be operated from the base of the wind tower to pull the machine out of the wind.

The design provides that if this chain mechanism ever breaks, the resulting tail vane movement automatically steers the rotor out of the wind.

A wind rotor has to turn constantly and track the wind, and designing for this is another problem facing the do-it-yourselfer. Matthews attached the generator to a pipe shaft and used a tapered roller bearing to provide for a turntable. The bearing came from the rear end of a two-ton International truck. Above the bearing, a disk from a piece of old farm equipment was used.

A triangular metal plate was welded into the tower to hold the other end of this shaft.



With a little help from his friends, Matthews attaches the wind rotor to the generator/ transmission.

Still farther down the tower, a black cylindrical unit holds the slip ring assembly. In here, electrical power is transferred from the moving generator to the fixed electrical transmission line.

Because wires from the turning generator would get tangled, electrical brushes in contact with rotating slip rings are needed to transfer the power.

Finally, the electrical power needs to perform useful services. If the General Electric alternator is turning at the proper speed whenever electricity is needed, there's no problem.

Often, for this wind-driven system, this will not be the case. Three options for solutions were discussed:

1. Using rectifying diodes to change alternating current to direct-current power to charge a battery bank.
2. Using a synchronous inverter that allows a utility company tie-in.
3. Dissipating the electricity through a heating coil into a hot-water tank for storage as heat.

PERFORMANCE AND OPERATING HISTORY

This wind machine was installed in early 1981 on a 20-foot tower. After overcoming initial difficulties during the testing period, a larger tower was employed. The rotor seemed to start turning in light breezes and with stronger winds, good electrical output was noted.

Randall Richardson's firm, Custom Towers at Harrison, did some troubleshooting on the project.

Matthews said he felt that losses in the transmission gear box reduced power by 20 percent, in comparison to a direct-drive arrangement.

A vibration problem in high winds led to blades crashing to the ground and rotor hub damage after a few weeks of operation. After this rotor-balancing problem was corrected, the wind machine worked fine.

It had been operating without major problems for months, at last report. The electricity was being used to heat water, although plans for battery charging were in progress.

The wind machine now provides electricity to heat water for the Matthews' home.

COSTS AND BENEFITS

Matthews invested about $1,500 total and untold hours of labor. Much of that expense went for the General Electrical generator at $500 and the transmission gearbox at $515. The blades were built for about $15 each.

At a good Ozark wind site, this wind machine could produce 250 to 500 kilowatt-hours per month of electricity. That would translate to a savings of $240 to $480 per year — based on eight cents per kilowatt-hour in this utility area.

That would lead to a fairly rapid payback period, assuming no major repair costs and a durable machine.

FOLLOWUP INFORMATION

For a slide show on this project, see Slide Program 34 *A Four-kilowatt Homebuilt Wind Machine* at the North Arkansas Community College Library.

Dr. Richard Komp Taught Arkansans to Assemble Photovoltaic Panels at Harrison

Dr. Richard Komp
Skyheat Association
Route 2
English, Indiana 47118
Government Grant: None
In June, 1982, Six Photovoltaic Panels Were Built at North Arkansas Community College.

BACKGROUND

A workshop on building photovoltaic modules was held at North Arkansas Community College at Harrison, Arkansas in June of 1982.

Dr. Richard Komp, Joel Davidson and Stephen Cook were instructors to the class of 40 interested in learning about photovoltaic (PV) modules.

The class built four 6-watt flat-plate photovoltaic modules and two hybrid concentrator-type photovoltaic modules, each capable of furnishing between 18 to 33 watts of electricity — depending upon use and type of reflectors — and several gallons of hot water daily.

The high cost of photovoltaic solar electricity prevents most homeowners, even those wildly enthusiastic about solar energy, from even considering using solar cells to generate their home's electricity.

Making solar cell panels completely from scratch, starting from pure silicon, is a high-technology, capital-intensive venture far beyond the means of even the sophisticated do-it-yourselfers; there is, however, another approach.

It is possible to buy commercially-made individual solar cells, solder them together, and encapsulate the whole thing into a finished panel. Whether this is a money-saving way to get solar electricity depends critically on two factors:

1. The skill with which the photovoltaic panel is assembled; and
2. The cost and quality of the individual solar cells used in the assembly.

This workshop, conducted by Dr. Richard Komp, a physicist who has helped hundreds with assembling photovoltaic panels, provided instruction and hands-on training.

A workshop participant solders lead wires onto his photovoltaic panel.

The objective was to help the prospective photovoltaic panel-builder put together a high-quality panel with a long lifetime for a modest cost.

Before providing building instructions for the six-watt module, a description of the hybrid module is in order.

The hybrid panel was built on a 5½ × 76-inch aluminum extension fin, which had a ⅝-inch copper tube bonded to its back.

Water circulates through the tubing and is heated by waste heat. This comes from sunshine not converted to electricity by the solar cells, which typically are 10 to 15 percent efficient.

The solar cells employed here can tolerate

MATERIALS

(For One Flat-plate Six-watt Photovoltaic Module)

Quantity	Material
35 (or so)	Rectangular 1 × 2-inch solar cells
1 each	Multimeter or volt meter and ammeter of appropriate ranges
1	Solar cells sample holder [1]
	B&G Number 24 or Number 26 copper wire, for cell interconnects, or Multistranded Number 16 or Number 18 copper wire, using individual strands
	Solder: 60 percent tin, 38 percent lead and 2 percent silver
1	Pencil-type 35 to 40-watt soldering iron
	Rubbing alcohol, (for cleaning cell surface contacts before soldering)
	Cotton swabs
	0.1-inch-thick extruded acrylic sheet (for panel box)
	Utility knife for cutting acrylic
	chloroform (solvent glue for acrylic)
	eyedropper for applying glue
	4-40 brassheaded screws
	1/16-inch-thick polyethylene foam packing material
	Silicone caulking

[1] This was built from a 6 × 8-inch plywood base, wires, and electrical binding posts. The construction is such that good electrical contacts with back and finger cell contacts can be made without shading the solar cell.

some concentrated sun — unlike many cells, which will be damaged by more than 1.5 suns. Suns refers to a measure of sunlight concentrated to more than normal brightness. So, Winston concentration reflector wings may be added.

PROCEDURE

1. The individual solar cells were tested using a multimeter. A cell was put on the test holder and put in the sun. Open circuit voltage was tested on the 0 to 1 volt scale. Readings of 0.55 volts were typical.

   Occasionally, defective cells with low or no output were found. Sometimes it was possible to locate the "short".

   More than one cell was fixed by using a knife to scrape off solder that had spilled over onto the back, thereby shorting positive and negative contacts. The testing proceeded until a set of 32 good, matched cells was found.
2. Interconnect copper jumper wires were soldered onto the contacts of each cell. Two or even three redundant wires were attached for multiple contacts in case one failed. Contact surfaces were cleaned and fast soldering done with a hot iron.
3. Altogether 32 cells were then interconnected in series hookup by soldering. Three rows of 11, 10, and 11 cells were employed. The wire interconnections were arranged so that they had a slight bend when cells were finally positioned in the case, to provide for possible expansion.
4. A flat acrylic box 9 × 10 inches was built to house the three rows of cells.

   Half an inch was allowed between rows and at each edge. Cutting the acrylic was done by scoring it with a knife and breaking it along the score by bending. Quarter-inch spacer strips to use between row and edge supports were also cut.
5. The bottom and spacer strips were glued together with chloroform, using an eyedropper. Instructors emphasized the hazard of the material and urged great caution, to avoid breathing it or getting it on skin. A few drops between cracks and a few minutes' drying time are needed.
6. The cell assembly was lifted into place — carefully — in the box. Two small holes were drilled in one end of the box to bring the negative and positive lead wires out. These were sealed with silicone caulk.
7. The cell assembly was then tested for current and voltage output before the cover was fastened.
8. Holes were drilled and brass screws used to secure the cover. Silicone caulk was employed as a sealant around the edge.

   This cover can be removed later if necessary. A better seal —suitable even for marine applications — can be obtained using chloroform again, but this cover cannot be removed.

PERFORMANCE AND OPERATING HISTORY

Testing of the flat-plate module (open circuit) showed 18 volts and 0.45 amps or 8.1 watts.

The nominal 6 watts was conservative. Modules sealed like this one have reportedly been operating for two years without any decrease in electrical output. Similar reports of good performances from hybrid modules like those built here have been recorded.

As much as 30 percent more electricity can be obtained from this design by building the reflector of aluminized Mylar instead of plain aluminum flashing.

There was no time to build the reflector wings at this workshop.

COSTS AND BENEFITS

All of the six modules built were purchased by workshop participants. The nominal 6-watt ones sold for $105 each and the hybrid ones, including aluminum flashing wings, sold for $240.

In the ideal case, it may be possible to build a photovoltaic panel with a lifetime and output similar to a commercial panel and save 25 to 50 percent.

It's also possible — this is the unfortunate case — to build something with very low output and short lifetime, and spend an amount comparable to what a competitively-priced, first-quality commercial panel would cost.

One workshop participant reported results

resembling the "unfortunate case" in describing his after-the-workshop experiences with assembling photovoltaic panels. It is not known whether the cells or assembly techniques were at fault, although the cells were suspected.

FOLLOWUP INFORMATION

Komp's book *Practical Photovoltaics* contains a whole chapter on assembling photovoltaic panels and is highly recommended.

Slide Program 49, *Assembling Your Own Photovoltaic Panel,* available at the North Arkansas Community College Library, documents the workshop.

Photovoltaic Array at College in Harrison Teaches Hundreds About Solar Electricity

North Arkansas Community College
Pioneer Ridge
Harrison, Arkansas 72601
Telephone: 743-3000
Stephen Cook
CompuSolar
Gum Springs Road
Jasper, Arkansas 72641
Telephone: 446-2211
Project Grant: $9,930
Solar Enthusiasts Installed a 660-watt Photovoltaic Array with a Battery-charging Application.

BACKGROUND

In May 1981, power at the switch in the North Arkansas Community College Energy Center came from electricity generated by the sun.

The impact of this photovoltaic array/battery room installation has gone beyond delivering electricity to run the Energy Center's lights and microcomputer.

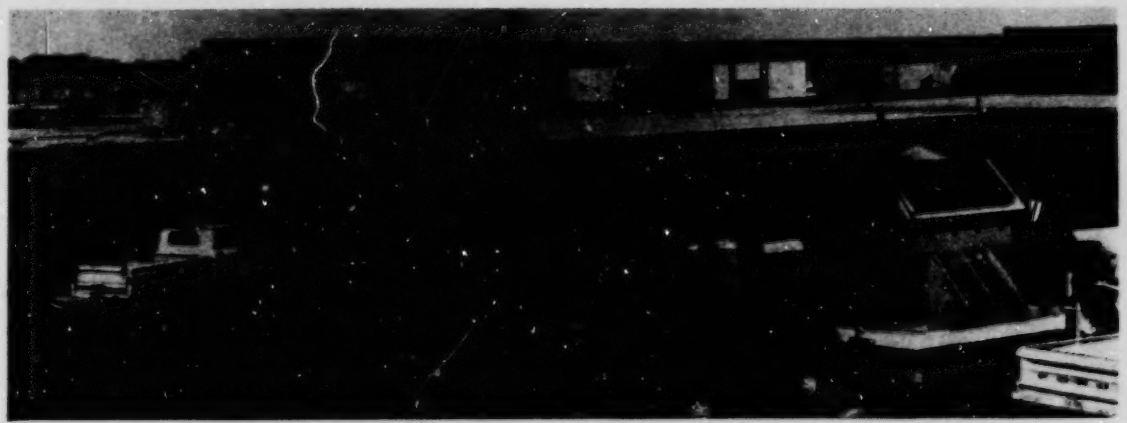
For example, it has been used in instructing about 125 people who took minicourses or workshops on solar electricity at the college. Many of those people subsequently used photovoltaics to supply all or part of their home's electricity.

Thousands of other people have been exposed to this photovoltaic installation through tours, slide presentations, or newspaper and television accounts of the installation, by the time of the final project review in June, 1983.

Even its planning drew considerable attention; purchase of its 20 ARCO modules sparked a bulk purchase of photovoltaic modules for Arkansas buildings that gained national attention in *Solar Age* magazine.

RENEWABLE ELECTRICITY GENERATION

Twenty ARCO Solar ASI 16-2000 photovoltaic solar modules, providing a peak 660 watts,



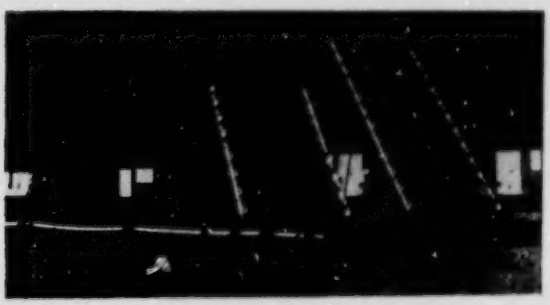
The photovoltaic array atop the North Arkansas Community College on Pioneer Ridge supplies electricity to the Energy Center and acts as a teaching tool for those interested in solar energy. A mobil solar demonstrator (lower right) is also used for instruction.

are mounted on the roof of the maintenance building at the college. They are rack-mounted at a 40-degree south-facing angle.

Eight special steel angle brackets were made to bolt the feet of the south-facing racks to the roof. These also help raise the assembly slightly off the roof and above any snow accumulation.

The system actually is composed of five separate blocks. Each block consists of:

1. Four 33-watt solar modules hooked together in parallel with Number 8 copper wire to provide a maximum of 132 watts of 12 volts direct current power (10 amps)
2. A hundred feet of Number 6 aluminum underground lead-in wire that runs along the building's roof inside a two-inch polyvinylchloride (PVC) pipe kept up off the roof by well-placed concrete block supports. This connects the two PV output terminals to the battery room control boxes.



PVC pipe supported by concrete blocks houses wires connecting the photovoltaic array to the battery bank.

3. The ARCO Village Power Panel control box. This solid-state device prevents battery overcharging by cutting off the charge when a battery voltage of 15.1 volts is reached. It assumes float voltage of 14.2 volts at two amps.

   It also prevents too deep a battery discharge, by disconnecting load and battery bank when 11.2 volts is reached.

   It reconnects these when recharging brings the batteries back up to 13.0 volts. The control box also can distribute three loads of up to 5 amps direct current each (15 amps total) and has built-in circuit breakers.

ELECTRICAL STORAGE AND BACKUP

Six used 6-volt C&D 3KCT 180 amp-hour batteries for each block are hooked in a series/parallel combination to provide 12-volt, 540 amp-hour storage.

Flame arresters are on each of the three cells per battery. The batteries are mounted on steel battery racks made by the C&D Company. Utility-supplied alternating-current power is available for backup.

ELECTRICAL LOAD DESCRIPTION

Each of four blocks power a load of two 40-watt fluorescent lights inside the Energy Center. Each light has a special ballast (made by IOTA Engineering) that requires 12-volt direct-current input.

Block five runs a Sinclair ZX81 microcomputer and its video display terminal. The computer, which requires 9 volts of direct current, is hooked into a converter, which takes 12 volts direct current and transmits 9 volts direct current.

The lights are operated by a 4PDT toggle switch on the wall in the Energy Center. Individual switches on the control boxes inside an adjacent battery room can override this switch.

Backup alternating-current fluorescent lighting — six 40-watt bulbs — is available should the solar-powered lighting be unavailable for some reason.

The computer and video display tube plug into 12-volt wall-mounted outlets. Instantaneous battery voltage and output current are displayed on gauges. An amp-hour meter records electrical energy production.

PERFORMANCE AND OPERATING HISTORY

The array has often been observed producing 52.5 amps at 12.8 volts (672 watts) around noon on very clear days. The white rock roof on which the array is mounted is believed to increase output through ground reflection.

Monitoring of monthly production has not

lead to significant results because of two problems:

1. The voltage regulation equipment reduced — sometimes to zero — the current fed into the batteries by the array when the batteries were near maximum charge. This wasting of power would have been insignificant had not the batteries often been in this fully-charged state.
2. The control-box charge controller's operation was sometime erratic, possibly because of low temperatures in the battery room in winter, and moisture problems brought on by a troublesome roof leak during heavy rains.

It was a mistake to install the control boxes in a largely unheated room, since specifications require temperatures above 32 degrees.

Sometimes the control box would falsely sense a low voltage and decouple batteries and load. This contributed to the fully-charged battery state and problems listed earlier.

A sophisticated computer study of this installation led to the predicted monthly "electricity available to run the load" figures.

These are based on historical average sunshine records. In October 1981, a month when the monitoring problems cited were minimal, 53 kilowatt hours available to the load was recorded.

The used batteries were purchased, fully tested, for a fraction of the original price. They were three to 10 years old at installation, and have not performed as well as had been hoped.

The effective amp-hour capacity has been judged to be only a fraction of the name plate rating. Project workers concluded that the older and poorer batteries in each block have pulled down the performance of the others.

These batteries also provided the biggest installation headache; cleaning battery terminals, lead-lined copper straps, and brass bolts was the most time-consuming part of the installation, requiring perhaps 45 hours total.

Nitrous-oxide grease was used to coat each battery terminal to fight corrosion.

With the batteries usually near full charge, loss of electrolyte was more of a problem than at PV installations where batteries are not in that condition. Battery maintenance — the addition of distilled water — was necessary once every month or two.

PERFORMANCE OF 660-WATT PV ARRAY AT HARRISON

With a tilt angle of 40° south; ground reflectance of 0.4; a battery efficiency of 0.8; a distribution factor of 0.9; and assuming an additional 10 percent array output derating factor.

MONTH	KWH per MONTH
JAN	46.81
FEB	50.30
MAR	60.74
APR	62.84
MAY	66.30
JUN	66.30
JUL	69.20
AUG	67.67
SEP	57.99
OCT	59.20
NOV	48.40
DEC	42.10
ANNUAL TOTAL KWH	697.00

Note: Our analysis shows a predicted annual kilowatt-hour output of 732.3 (i.e. a 5.1 percent increase) if the tilt angle were adjusted once a month to the LAT-DEC optimum angle.

COSTS AND BENEFITS

Chief expenses were: 20 photovoltaic modules,$6,300; 30 batteries,$780; photovoltaic mounting racks,$360;5 VPP charge controllers,$375; and monitoring equipment,$300.

The entire project was funded by a $9,930 grant, which excluded labor expenses.

The chief benefits of this project have been educational.

At these prices, PV systems clearly have unacceptable payback periods where regular utility service is available.

FOLLOWUP INFORMATION

Slide program 35, *A 660-watt Photovoltaic Installation*, available at the North Arkansas Community College library, documents this project.

5 Biomass

Arkansas Farmers Make Methane From Manure and Fuel Alcohol From Corn

Examined here are two bio-conversion processes — digestion, producing methane, and fermentation and distillation, yielding grain alcohol (ethanol) — and one thermo-chemical conversion process, gasification of wood giving a gas with a low Btu output.

METHANE

Bacteria inside a methane digester produce biogas from animal manure or plant wastes. The biogas, mostly methane and carbon dioxide, can be cleaned, so that the resulting gas is nearly pure methane.

Methane makes up typically 95 percent or more of natural gas.

Safety is important at methane digester installations and that is best illustrated by the fire that occurred at New Life Farm at Drury, Missouri.

The James Keel project sought to employ the gas for motor-vehicle fuel.

One of America's leading digester companies, Perennial Energy, benefited from expertise gathered in building and operating the digester at New Life Farm.

ALCOHOL

The Arab Oil Embargo of 1973 stimulated interest in making fuel alcohol from agricultural products. That interest paralleled rising gasoline prices and dropped after gasoline prices peaked and then came down.

The Arkohol experiment at Scranton and the Yellville alcohol plant were born in the first part of this cycle and eventually their production activity became dormant, in line with national activity.

Unlike methane production, the cost-effectiveness of alcohol fuel production can be readily assessed, by figuring the cost per gallon of the fuel produced. More difficult to determine is the net energy balance of the process.

From an energy-saving viewpoint, there is no point in making this fuel if it takes more energy to make it than it yields. Energy usage at each step of the production process must be minimized.

Gasohol, USA is a leading periodical for this technology and is a valuable resource for those interested in alcohol production.

PRODUCTION PER 1,000-POUND ANIMAL WEIGHT

TYPE ANIMAL	CU. FT. BIOGAS PER DAY	VALUE OF PROPANE[1] REPLACED/YEAR	VALUE OF ELECTRICITY[2] REPLACED/YEAR	VALUE OF HEAT RECOVERY[3]/YEAR
Beef	30	$ 58.40	$27.27	$17.52
Dairy	44	82.73	45.72	29.20
Poultry, layers	72	136.26	73.14	46.72
Poultry, broilers	92	175.20	91.43	58.40
Swine	29	53.53	26.36	17.52

[1] Propane valued at 80 cents per gallon.
[2] Electricity valued at 6 cents per kilowatt-hour; 25 percent efficiency.
[3] Heat recovery from engine generation; 40 percent recovery.

Courtesy of Perennial Energy

WOOD ENERGY

To most Arkansans, wood energy means the wood heating stove. The Harrison Fire Department pursued one interesting program relating to wood heat safety, by providing the tools for chimney cleaning to the public, a service that saved lives and property. Statistics show that when a home fire starts at a wood stove, improper installation or maintenance is most often the cause.

Dale Bliss at Bluffton built a wood gasifier that is still at work. Wood gasifiers have been used to power vehicles but this application is plagued by the practical difficulties of loading a solid fuel, maintenance and the dirty nature of the technology.

One interesting sidelight to Bliss's work is the fact that the gasifier he tested can be fueled by fossil fuels like coal, as well as wood-derived fuels (charcoal).

Dale Bliss Creates Producers' Gas at His Bluffton Farm, Using Wood

Dale Bliss
Star Route
Bluffton, Arkansas 72827
Telephone: 299-4663
Government Grant: $3,365
A Wood Gasifier That Creates Producers' Gas Operates in Yell County.

BACKGROUND

Producers' gas or wood gas is created by the controlled burning of wood in a closed container. A blower or vacuum system directs air through a nozzle into the container. The fuel is ignited at the tip of the nozzle and the gasification process is controlled by regulating the air flowrate and temperature.

Typically, the fuel is fist-sized, or smaller. High temperatures produce the gas.

Much of the energy content of the resulting wood gas comes from its hydrogen and carbon-monoxide content — each typically is a fifth of the total — although other gases including methane, carbon dioxide, acetylene and nitrogen are present.

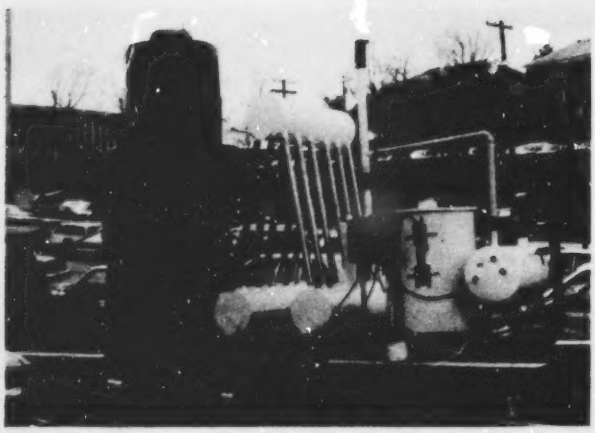
The hot gas exits the container through an opening, about four times the air nozzle size, below the fire zone grate. It is then sucked through a series of cooling tanks and filters.

The gas must be cooled to below 100 degrees before it can be fed into a stationary internal-combustion engine. Filters remove tars and resins, which can clog the engine.

Wood gives off a fair amount of these when compared to charcoal, which is perhaps a cleaner, more desirable fuel for this application.

TEMPERATURE EFFECT ON GAS COMPOSITION

TEMPERATURE DEGREES FAHRENHEIT	GAS COMPOSITION NOTES
340 - 550	excessive moisture and smoke
550 - 900	steam, tars, acid, methyl alcohol
Above 900	carbon dioxide changes to carbon monoxide
Around 1,200	hydrogen gas released from moisture
Above 1,300	there is no tar in the gas; the hydro-carbons have burned
Above 1,600	there is good production of carbon monoxide and hydrogen



Dale Bliss with his old system at his home in Bluffton (left) and demonstrating his new system at the State Capitol (right). The new system employs more automation resulting in higher efficiency.

PROJECT DESCRIPTION

In April 1980, Dale Bliss set up what he described as "an old rusty contraption" that generated and burned wood gas to make electricity and hot water at the Arkansas Energy Resource and Development Fair in Little Rock.

Though the fair exhibits included the latest equipment for making alcohol or methane gas, Bliss's unit, which refueled with woodchips and charcoal, caught the crowd's attention.

Bliss was constantly making adjustments and overcoming problems to keep the gasifier, built largely from salvaged parts, running a stationary engine. However, most saw the promise once the problems were solved.

One fairgoer summarized the feelings of many:

> Of all the things I've seen here this is probably the only one I think I might be able to afford. And who knows, with all the waste wood we've got, it might prove to be real practical.

Nearly two years later, in January 1982, Bliss was back in Little Rock, this time at the Capitol, demonstrating a new improved gasifier. His new model burns mainly charcoal, but he has burned coal and plans to try lignite and coke.

Bliss describes his new gasifier this way:

> The round tank (white) holds the filters; the three tanks (hooked together) with the pipes are the cooling unit. The black tall tank is the main fuel container with the air supply system. The three air nozzles have high-temperature glass so one can watch the firezone and also make sure the nozzles are not slagging over, which reduces the air flow. The pipe you see sticking up between the filter and the cooling tanks (with the black top) is the fuel test pipe. This is used for start up before switching (gas output) to the filter tank.

PERFORMANCE AND TESTING

Test results for the gasifier fueled by charcoal — at a consumption rate of 45 pounds per hour — indicate that 255,000 Btu's per hour of energy was delivered to the engine.

The resulting 3,400 Btu per pound represents a gasification-conversion process efficiency of 49 percent. Gas was delivered at an average flow rate of 17 cubic feet per minute, which works out to an energy content of 250 Btu per cubic foot.

During operation, Bliss measured gas temperatures of 320 degrees going into the cooling system; 98 degrees coming out; and 92 degrees going into the engine.

COSTS AND BENEFITS

Bliss has $7,000 invested in his latest gasifier unit. Chief expenditures include:

Main gasifier container	$ 856
Air supplying nozzle system, hot gas discharge piping	1,340
Cooling system	785
Filtering system	277

Potential applications of similar gasifier units include grain-drying, poultry-farm uses, industrial-boiler systems, and stationary engines at sawmills and chip mills.

This technology allows replacement of gasoline, diesel, fuel oil, natural gas, or LP gas with solid fuels such as coal, lignite, and charcoal.

Ed Davis, Biomass and Resource Recovery Program Co-ordinator for the Arkansas Energy Office, said that the Bliss gasifier could indicate "that this process may be extremely cost effective in applications where an abundant low-cost supply of the fuels is close to the area of use."

He goes on to suggest:

> Economics could further be enhanced by more automation in process monitoring and operation, as well as automatic residue removal, which would facilitate continuous operation 24 hours per day. These changes, though involving greater capital cost, could more than double the rate of payback on the system.

Scranton Farmers Sought Energy Self-sufficiency Using Solar and Alcohol Fuels

Evelyn Lowe
Arkohol
P.O. Box 345
Scranton, Arkansas 72863
Telephone: 938-2893
Government Grant: $50,000
An Alcohol Fuel Production Facility Was Placed So That Waste Heat Went to a Solar Greenhouse.

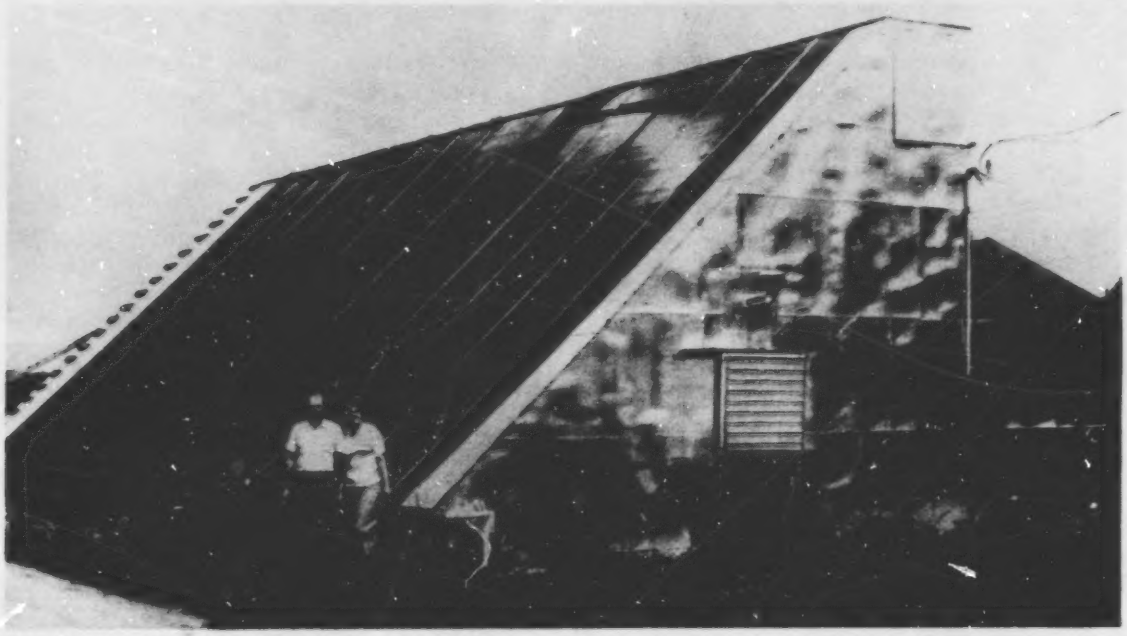
BACKGROUND

Scranton is a farming community of 250 families on the Arkansas River in west-central Arkansas. Grain, dairy and beef cattle, and broiler operations make up the bulk of the local economy. In early 1980, after the fuel shortages of 1979, gasoline cost $1.30 per gallon and was expected to go to $2 per gallon by the end of the year.

Fifteen Scranton farm families launched an ambitious project to deal with this problem. In applying for federal funding, they spelled out their concerns and plans:

It is the concern of this community that they will be particularly traumatized in the event of drastically-reduced fuel supplies, just when their need is greatest, during peak farm activity periods. They further worry about farm surpluses caused by unsettled market conditions because of embargoes or other world events.

This tiny community, which has already provided for their own community water supply, and recently bought and piped in their own natural gas system, after the area's utilities company declined service to such an isolated group, now looks to



H. B. Claunch and Evelyn Lowe stand outside the Arkohol project at Scranton.

substituting renewable energy resources (solar and alcohol) for their present nonrenewable resource (gasoline, diesel).

However, along with all that concern about the uncertainties of global fuel supplies and market conditions, these Scranton farmers had another concern.

This was something closer to home and more personal in nature: many of them felt unproductive during the cold weather period between harvest-time and spring planting. That led to another project, integrated with the production of alcohol fuel.

These plans revolved around building a solar-heated commercial greenhouse to use the off-season labor of the area to raise fresh produce for sale to local markets. Recycling heat from the alcohol distillation unit, as well as carbon dioxide from the fermentation process in the greenhouse, linked together the two projects.

In late 1980, after much organization and planning, actual construction work began. After much hard work, and with the help of $50,000 in federal funds, both projects became a reality in the spring of 1983.

The greenhouse employs 1,200 square feet of Exolite, a double-layered acrylic glazing. Its dimensions are 28 × 60 feet.

In the center of the greenhouse, sunk into the ground, sits a concrete heat-storage tank. The wood frame construction includes a north wall insulated to R-11 with fiberglass, and east and west walls insulated to R-4 with Thermoply insulation board. A shade cloth and large cooling fan supply summer cooling.

None of the farmers involved in the project had any greenhouse gardening experience. Most were dairy farmers who grew hay, milo and silage. Two project members finally enrolled in horticulture classes at Arkansas Tech University at Russellville for some badly-needed know-how in that subject.

CONVERSION PROCESS

Pre-ground milo grain was the starting material in preparation of a mash for alcohol production.

Mash cooking recipes from *The Mother Earth News Handbook of Alcohol Fuel Production* were used. After fermentation, the "beer" was distilled in a single-run process yielding 15 to 25 gallons per hour of 170 proof alcohol.

The alcohol plant sits in the east end of a broiler house 340 feet long. It is located within a 36 × 40-foot concrete partition.

The mash cooker was made by placing a surplus milk tank over a firepit stove. Little modification of it was needed. Stirring the mash was accomplished by using the electric-motor-driven agitator once used for stirring milk.

This tank was elevated so gravity transferred the mash to the fermentation tank. This was a 500-gallon, surplus, stainless-steel tank, measuring 3 × 5 feet.

A heat exchanger coil was employed inside this tank to keep the mash at 85 degrees for fermentation, with hot or cold water used to adjust the temperature if necessary.

A transfer pump moved the beer to the distillation unit. The distillation unit, an original design, is 13 feet high and its square cross-section shape resulted from the original heat exchangers employed — surplus Chevrolet air-conditioning system heat exchangers.

The column cross-section is variable, ranging from 1 square foot to 3 feet at the base. Arkohol workers describe the "still" this way:

> The distillation unit utilizes a center core which forms the boiler portion of the "still". This center core is enclosed in a shell which forms the reflux chamber.
>
> The lower reflux chamber houses open-ended finned tubes standing vertically, arranged around the center core. The upper unit has two heat exchanger sections located directly above the center core. Proportional flow temperature probes, valves and gauges regulate the temperatures in the separate heat exchanger sections by controlling the cooling water through them. These heat exchangers are thus controlled to maintain a desired temperature for a molecular mixture at that point, drawing off as much as possible for the alcohol vapors and returning more and more water to the lower column. Offset from the distillation column, an internally-cooled condensation chamber is connected to the column.

The still has a unique feature that enhances operation: the heat exchanger used at the top of the condensation chamber creates a low-

pressure area there.

This causes the entire process to operate at slight negative pressure or in a mild vacuum. This is advantageous because the liquid requires less heat to vaporize, making the operation both less energy-intensive and safer.

The heat exchangers employed are homemade copper coil successions. The entire distillation stack is encased in fiberglass insulation. The heat for both cooker and distillation unit is supplied by wood. The smoke from the distillation firebox is routed under the elevated cooker before exiting the building in one heat-recovery scheme.

The low-grade heat in the return lines of the heat exchanger was piped to an 18,000-gallon concrete tank inside the adjacent greenhouse. The tank measures 20 × 20 × 7 feet. This hot water was then circulated through the greenhouse.

This was accomplished by surplus heat-exchanger units, installed in the floor and north wall. The exchangers measure 7 × 10 feet. The tank also receives some heat from solar radiation.

BIOFUEL END USE

Six vehicles, including Chevrolet trucks, cars, and one Ford Pinto, were converted to run on the 170-proof alcohol. The conversion was accomplished by first tuning the vehicle for good gasoline performance, then boring the carburetor, advancing the timing and — in one case — increasing the compression ratio.

The conversions were done using surplus carburetors in such a way that, if necessary, the vehicles could be restored to gasoline operation.

One very cold night, alcohol was burned in the greenhouse in makeshift "hobo" stoves to provide both heat and carbon dioxide for the wilting plants.

WASTE BY-PRODUCTS USAGE

The Arkohol group has outlined, though not yet implemented, plans for using the spent grain by-products of distillation.

These plans called for recovering 25 percent of grain solids from the fermentation process. Using heat recovered from the distillation column, the group planned to dry the solids and use or sell this as feedstock. This "feed" may yet fatten some cattle around Scranton one day.

PERFORMANCE AND OPERATING HISTORY

Falling gasoline prices removed the incentive for making fuel alcohol. According to Arkohol project reports:

> During the course of this project, we have watched the pump prices of gasoline recede from $1.49 per gallon, to 93 cents per gallon. Currently, it is $1.16 per gallon in this area. While we have shown that we can compete favorably with that price (alcohol costing $1.10 to $1.25) the additional cost of converting vehicles to alcohol operation, as well as the unavailability of alcohol pumps on the road, makes this procedure economically unfeasible at this time. Grain prices have also escalated markedly since this project began, as have materials and labor. But should conditions arise approaching the oil crunch of 1979/80, we feel we are ready to meet that crisis head on.

Workers proudly display produce grown at the Arkohol greenhouse.

The plant produced no more than 100 gallons of alcohol fuel. Five of the converted vehicles have been restored to gasoline operation.

The distillation column design did prove to be energy-efficient, although the alcohol it produced was lower in proof than desired. This was due to the homemade heat exchanger limitations.

The project sponsors reported:

> We are now able to get 170 proof alcohol with one run, using a 9-10 percent beer. We have determined that we are close enough to the results we want to actually make 190 proof alcohol. What would be entailed, however, is again tearing into the distillation column, removing the homemade, limited-surface area heat exchangers, and replacing them with heat exchangers which we have now located and purchased, which are suited to our "still" shape, have several times the surface area of ours, and which are a manufactured, heat-transfer-tested product. We would also add one chamber with its own heat exchangers and proportional flow temperature probes and gauges. This would only add 18 inches to the over-all height of the column. We would still stay within the limits of the broiler house by rotating the condenser chamber, bringing it into the plane of the roof peak (a 90-degree rotation). From every indication, this would be enough to bring us the higher proof alcohol.

Before the distillation unit worked at all, there were problems. The initial surplus heat exchangers, although rated at 300 pounds per square inch, failed under the surge pressures of the opening and closing of the cooling water valves.

These valves also were suspected when there were difficulties in regulating the temperatures in each column section. The "full on/full off" nature of the valves, which brought a burst of cooling water into the heat exchangers, was the real problem. The situation was finally remedied with the installation of the proportional flow system.

When finally perfected "the whole system was so simple, we experienced no shut downs for clogging or backup when the plant was in operation," according to Arkohol officials. According to one member, Arkohol may start up fuel production again if gasoline gets to $2 a gallon.

The problem of no alcohol pumps available on the road to alcohol-powered vehicles would be overcome by using a dual-fuel (gasoline or alcohol) conversion process.

Although fuel production has ceased, the distillation unit's firebox is still used to charge heat storage in the greenhouse. By the spring of 1983 — after the first winter of greenhouse operation — 18,500 tomato plants and more than 5,000 other vegetables and houseplants were ready for harvest.

For a while, this produce "fed Scranton and surroundings," Arkohol workers said, as the whole community became involved with the project.

Greenhouse heating was satisfactory. The project supervisors reported that "the heat-storage tank, drawing its heat from the distillation column waste heat, in addition to daytime solar gain, maintained a temperature of 62 to 65 degrees by day, dropping to 60 degrees at night, provided the greenhouse with an average of 60,000 Btu's per hour of nighttime usable heat."

Arkohol workers also note that during the first winter "no supplemental heater was used" in maintaining greenhouse temperatures.

COSTS AND BENEFITS

This entire project was financed by federal funding totaling approximately $50,000 and by $10,000 in outlays by Arkohol. Chief expenses include:

Alcohol plant equipment and material	$16,500
Labor expenses for alcohol plant	6,600
Greenhouse materials	10,000
Greenhouse labor	3,300

The Arkohol group concluded that the chief benefits were installation of an efficient fuel-production facility and the "know-how" ac-

quired in case they need to produce their own fuel in the future.

The greenhouse produce sales could prove to be a particularly profitable "off-season" venture.

Finally, the project demonstrated that several families can work together and successfully implement a project of this nature. An important benefit of this project was a rekindling of the community spirit, which it fostered.

Herman McCrory Produces Fuel Alcohol in Commercial Plant at Yellville

Herman McCrory, Sr.
W. Highway 62
Yellville, Arkansas 72687
Telephone: 449-4739
Government Grant: None
A Small-scale Alcohol Fuel Production Plant Was Established in North Arkansas.

BACKGROUND

Modern small-scale alcohol fuel plants consist of a feedstock storage and processing area, a mash cooker, fermentation tanks, a distillation unit and storage for both fuel alcohol and spent distillers grains.

The McCrory alcohol fuel plant can produce 100 gallons per day of 180 proof alcohol. The description that follows documents how the plant, which sits in a large warehouse-type building, was producing alcohol in the spring of 1981.

CONVERSION PROCESS

Thirty bushel sacks of corn are emptied by hand into a large hopper in beginning a day's fuel production.

The corn falls down the hopper chute, then is fed into a hammermill. The hammermill grinds it almost as fine as cornmeal. A large blower sends the ground-up corn, which must pass through size 60 mesh screen, through an eight-inch round duct and into the mash cooker.

Inside the mash cooker, about 15 gallons of water is added for each bushel of corn, or around 450 gallons total. The mash must cook for 30 minutes at 205 degrees, and then the temperature is reduced to 90 degrees and two ounces of Takatherm enzyme per bushel of corn — 30 ounces total — are added.

All the while an electric motor is turning huge agitator vanes and stirring the mash. After 30 minutes at 190 degrees, a pump is turned on that sends enough water into the cooker to bring the temperature down to 140 degrees.

Then a small amount of battery acid is added to adjust the pH to 4.5. Diazymse enzyme is then added, which converts the starch to sugar, and the mash is held at 140 degrees for another 30 minutes.

A Brix hydrometer is used to measure sugar content.

Then a small valve near the bottom of the cooker is opened to draw a small sample of the mash. A Brix hydrometer is used to test the sugar content, which should be around 15 percent.

Either more water or longer cooking may be needed, if the sugar content is too high or low, respectively.

When it has the proper sugar content, the mesh is usually left to cool overnight.

When it has cooled to between 80 degrees and 90 degrees, it is pumped to one of three fermentation tanks.

With the temperature around 85 degrees, approximately half a pound of brewers' yeast per bushel of corn — 15 pounds total — is added near the top of the tank. A quart or two of mash mixture is typically used to mix in the yeast.

This starts the fermentation process, which typically takes 48 hours. A temperature of 85 degrees is maintained by circulating hot water from a storage tank through a heat exchanger in the fermentation tank.

Bubbling, evidence of the carbon dioxide the yeast is giving off as it eats the sugar, ceases when the fermentation process runs its course.

The other waste the yeast gives off is alcohol, and a proof hydrometer can check the alcohol content of the "beer" at this point. Typically it is 8 to 12 percent.

The beer is pumped out of the fermentation tank and into a separator unit. Here vibration, cushioned by large springs, helps separate the spent grain from the alcohol. The beer is pumped into the wood-fired distillation unit.

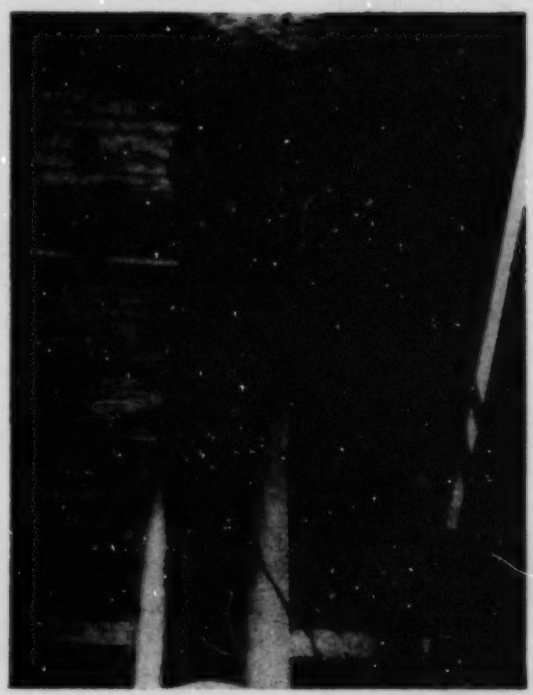
The 10 percent beer solution begins to vaporize near 196 degrees. In practice, some water turns to steam and leaves up the distillation column with the alcohol.

By controlling the temperature at various points and providing plenty of surface area for condensation inside the column, the alcohol vapor can be made to gather at the column's top and the water vapor condense to liquid and return to the bottom.

During distillation, the temperature at Point 1 is regulated to be near 195 degrees and at Point 2 to be 175 degrees to 180 degrees F. Point 3 is where the alcohol vapor condenses to a liquid. Very cold water runs through this condensing coil, lowering the temperature to around 105 degrees. The water used typically is at 60 degrees.

The 90-percent alcohol solution exits out a long pipe and into fuel storage.

The processing system has been designed for efficient operation. The hammermill is powered by a small gasoline engine. The mash cooker has 1,000 gallons capacity and is fired using wood slabs (sawmill waste). The fire chamber entirely surrounds the mash tank for more efficient heating.



Very cold water runs through the condensing coil in the column causing alcohol vapor to condense to a liquid.

The waste heat from mash cooking heats water in a 500-gallon storage tank, There are two such tanks for hot water storage. They contain sight gauges — transparent columns running from top to bottom, which have the same level of liquid as the tank itself, to show their capacity at a glance.

There are three 1,000-gallon, stainless-steel fermentation tanks, which are plumbed together. Each contains a copper-coil heat exchanger. Having three fermentation tanks allows for the daily production of alcohol fuel; there is no need to wait two days until the end of the fermentation process frees up a tank.

The distillation unit has a six-inch capped column. It has alternating sections packed with gravel, which provide a lot of surface area on which water vapor can condense.

The alcohol fuel is stored in a 400-gallon

After a simple conversion, a vehicle will run fairly well on the 180 proof fuel.

storage tank.

PERFORMANCE AND OPERATING HISTORY

For a while in 1981 and early 1982, the plant was supplying a Fayetteville service station with motor fuel. The station, which at the time was believed to have the country's only pump selling alcohol fuel, also was converting vehicles to run on 180 proof alcohol.

Spent grain from the separator unit, called distillers wet grains, is collected in a 55-gallon barrel. A barrel of this by-product, which must be used within two to three days before it spoils, is sold to local pig farmers for $15.

The plant can make 100 gallons of alcohol fuel per day. The distillation is continuous. One batch, at the rate of 10 to 12 gallons per hour, is collected and stored, while another batch is cooking and still another is sitting in a fermentation tank.

Nine to 10 hours per day of labor by one person is required. Six to eight wood slabs per day are needed to fuel the mash cooker and a similar amount is used for distillation.

Cleanliness has proven to be especially important. The fermentation tanks are washed down inside once a week and sterilized monthly.

COSTS AND BENEFITS

McCrory invested around $15,000 in the plant. The alcohol fuel cost $1.04 per gallon to produce, including a salary to the plant operator and sale of the spent grain.

This figure is based on corn costing $3.50 per bushel. The alcohol fuel was being sold in Fayetteville in mid-1981 for $1.50 per gallon, at a time when gasoline cost $1.40 per gallon.

FOLLOWUP

Slide Program Number 36 at the North Arkansas Community College Library documents this project.

James Keel's Farm at Harrison Uses Methane as Well as Wind and Solar Energy

Colonel James S. Keel (Retired)
P.O. Box 763
Harrison, Arkansas 72601
Telephone: 741-6067
Government Grant: $25,020
A Methane Gas Digester — Plug-flow Type — Was Used to Create Motor Fuel and Farm Fertilizer.

BACKGROUND

Jim Keel of Harrison has operated his biogas digester on a 60-acre cattle farm since May 1, 1980.

However, when you visit the facility, renewable energy technologies other than the biogas plant are more immediately evident. It's hard to miss the 1.5-kilowatt Enertech wind generator, which supplies part of the house and farm electricity need; it is sitting on top of a 100-foot tower.

Visitors also spot the batch-type solar water heater, which furnishes hot water to maintain the 95-degree digester temperature, before they see the massive digester tank.

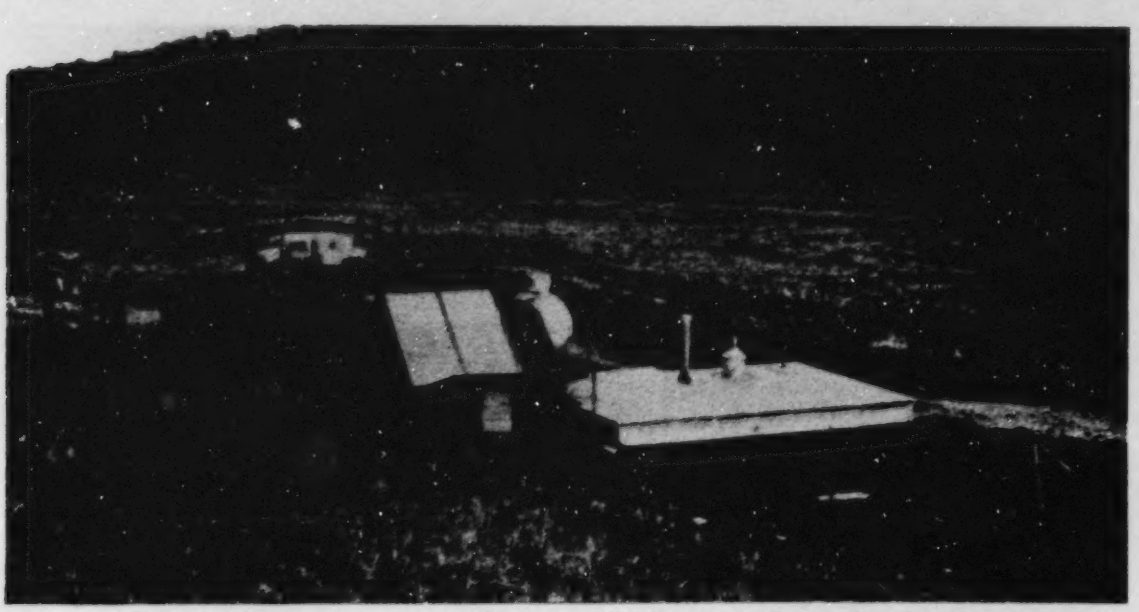
In fact, the 3,200-gallon tank is completely earth-covered — to minimize heat loss.

Unless you are inside the adjacent control room, where the end of the tank is visible, you'll never see it at all.

When you see Keel drive by in his six-cylinder Jeep pickup, remember that, chances are, he's running it on compressed natural gas, which is mostly methane.

Keel has dreams of running his truck on biogas; when he succeeds, he will complete his farm's energy cycle. The cycle would work this way:

A slurry made from cattle manure is loaded into the huge digester tank. The resulting gas is kept in a large storage tank for use. The wind



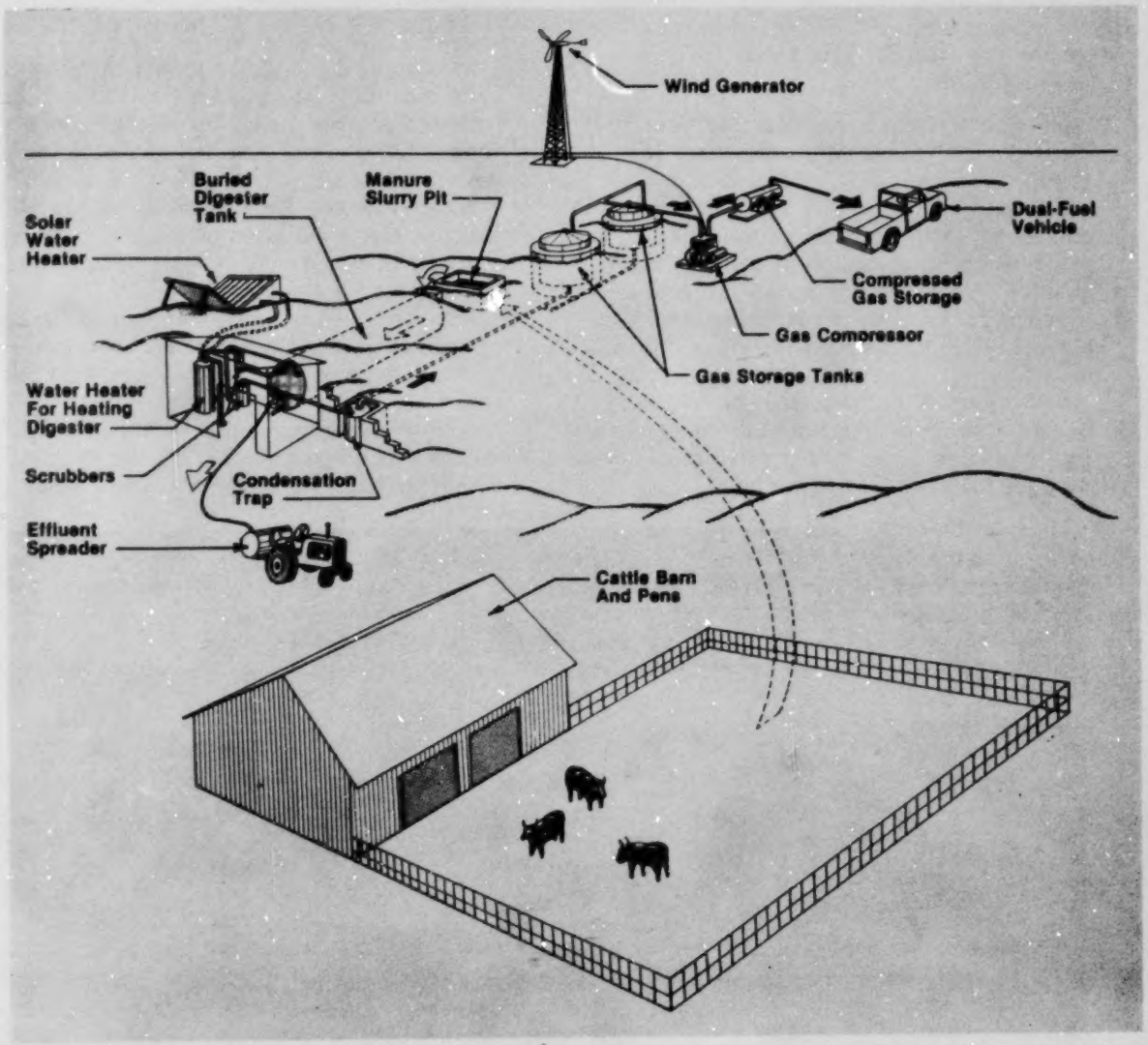
On James Keel's farm in Harrison, solar collectors are used to add heat to the digester. This heat is maintained by burying the digester underground.

machine provides the electricity to run the compressor, which pumps the methane into the truck's fuel tanks. The truck is used to spread the fertilizer, left over from the biogas plant operation, back on the pasture. The cattle feed on the pasture, provide the waste that goes into the biogas plant, and the cycle starts again!

One objection to compressing methane is that compression takes a good deal of energy and makes this a poor net energy proposition. The use of wind-generated electricity to run the compressor overcomes some of this negative argument.

Eight to ten adult cattle supply the manure for the digester.

The digester is initially loaded 90 percent full with slurry of one part manure to one part water. This represents 2,800 gallons. The plant operation is based on the practice of withdrawing 100 gallons of "spent" slurry — a rich fertilizer effluent — daily, and adding an equal



Schematic layout of Keel's system.

amount of fresh slurry that feeds the digester.

Each load of slurry moves in the digester to a point where the methane-producing bacteria are active. There large bubbles force their way to the surface, where gas accumulates. It exits through the dome of the digester and into the gas collection and holding system.

The gas runs from the holding tank through a two-inch line running alongside the digester. A condensation trap, carbon-dioxide scrubber, and hydrogen-sulfide filtration tank clean up the gas, and the methane is ready for use. A standard gas regulator maintains appropriate pressure.

One unfortunate by-product of digester operation is a coarse, fibrous material known as scum, which builds up inside the digester and must be removed once a year.

PROCESSING SYSTEM

The digester tank is five feet in diameter and 24 feet long. It is made of 3/16-inch thick steel. It holds 400 cubic feet or 3,200 gallons.

Four feet of earth cover the installation.

The control room, 8 × 14 feet, sits at the end of the buried tank, and itself is partly buried.

The digester cleanout access is through a 30-inch-diameter bolted port, visible in the control room.

The digester contains 100 feet of galvanized pipe routed through it, which carries hot water needed to maintain the 95 degrees for optimum production. The pipe is one inch in diameter.

A thermostatically-controlled pump regulates this flow. The hot water line also supplies the digester slurry-mixing basin, so that a hot slurry, which won't shock the digester operation, can be added.

A 300-gallon tank, cut in half lengthwise, is used as the mixing basin.

The gas collector and storage consists of an inner tank containing the gas, which floats inverted within the larger outer tank. The inner tank is 8 feet in diameter and 4 feet high. This outer tank is 9 feet in diameter and open at the top, but closed at the bottom.

It is filled with water to provide a seal. The seal keeps oxygen out of the system during plant operation. The 200-cubic-foot inner tank rises and falls according to the pressure of the gas within, riding on vertical tracks.

James Keel prepares the slurry for his digester tank.

This gas-holder tank in fact acts as an automatic pressure-release mechanism. It is weighted with hundreds of pounds of concrete blocks to provide the appropriate pressure. Here, that is standard four-ounce household gas pressure.

The gas line contains a standard, residential gas-flow meter and flame arresters.

The scrubber tank is half-filled with lime water and the filtration tank contains steel wool.

The gas is being used, or has been used for the following:

1. To provide hot water for continued digester operation in backing up the solar system.
2. In experimental running of a modified three-kilowatt, gasoline-engine standby electrical generator, whose use so far has been minimal due to mechanical problems.
3. Operating a vehicle on compressed biogas as part of a dual (gasoline/methane) vehicle conversion.

The last application deserves comment. The vehicle, a 1979 half-ton Jeep pickup truck, was fitted with a dual-fuel conversion kit.

This relatively-standard kit has an automatic spark advance, which automatically increases the timing when running on compressed natural gas (CNG). Mounted in the bed of the pickup truck are two tanks, which each hold the equivalent of 10 gallons of gasoline and take 4½ hours to fill. The tanks measure 10 inches by 56 inches and hold 191 pounds of gas at 5,000 pounds per square inch.

The refueling is usually done overnight with the compressor working in its slow-fill mode. Keel says that he doesn't need the fast-fill capability that is possible.

The compressor can provide up to 40 gallons gasoline-equivalent per day and uses a 3-horsepower, 15-amp, single-phase motor. Both it and the conversion kit were supplied by Ultimate Energy, Inc. of Tulsa, Oklahoma.

WASTE BY-PRODUCTS USAGE

The liquid digester effluent is withdrawn by gravity-feed through a three-inch hose hooked up to a 300-gallon spreader tank. The tank can be mounted on a truck or tractor for field distribution.

The pathogenic-free fertilizer is applied at the rate of 600 gallons per acre, every four days. Many consider the effluent to be more potent than chemical fertilizer and less risky to use; it doesn't inhibit earthworms or beneficial soil bacteria as the chemicals do.

PERFORMANCE AND OPERATING HISTORY

The Keel biogas plant produces about 400 cubic feet of biogas per day. High-quality biogas (mostly methane) will have an energy content of around 80 to 90 percent that of natural gas. This is the energy equivalent of about 2½ gallons of gasoline.

Conceivably, Keel could produce biogas that would displace a maximum of 900 or so gallons of gasoline per year that otherwise he would need for his truck. At $1.25 per gallon, the yearly savings would be over $1,100.

That assumes continual year-round gas production, and that little or no gas is returned for digester hot water. Clearly, the latter condition will not be met in severe, cloudy winter weather; the batch solar heater will not be sufficient.

Before the solar installation, about 25 percent of the gas was returned to meet these parasitic demands.

Unfortunately, an October 1982 testing of Keel's biogas, performed by a Tulsa, Oklahoma laboratory prior to attempting to run the Jeep truck on it, showed the quality to be rather poor. That and costs of the day influenced Keel's decision not to use methane as a vehicle fuel.

However, the truck runs on compressed natural gas when on the farm. It is not yet licensed for over-the-road use of the alternate fuel.

The performance indicates this fuel to be far superior to gasoline. According to Keel, the vehicle runs smoother, starts easier, gives more apparent power, offers the same mileage, and it is considerably cheaper to operate. Based on the current local natural gas rate of $2.80 per thousand cubic feet, the operational cost would be the equivalent of 28 cents per gallon!

COSTS AND BENEFITS

Around $8,000 has been invested in the biogas plant and another $6,600 for the compressor/dual-fuel conversion.

None of this includes the cost of the wind generator. Biogas producton savings of $1,100 per year is possible.

This project has not yet realized that return. So far, even comparing total project costs with the potential savings leads to an unimpressive payback period.

However, Keel considers another benefit: fertilizer. According to Keel, the fertilizer produced in one year replaces commercial chemical fertilizer at a projected savings of $2,268!

Al Boll Operates Methane Digester at His Farm Near Jasper

Alvin Boll
c/o Curt Boll, Sr.
Jasper, Arkansas 72641
Telephone: 446-2307
Government Grant: None
The Inspiration of a German Heritage Led to Construction of a Methane Digester.

BACKGROUND

Since the spring of 1978, Al Boll's biogas plant has been producing methane. The credit for that goes to Curt Boll, his father, who grew up in Germany in the early 1900s, and recalled that almost all of the larger farms had methane digesters.

"Bertha," as the Boll biogas plant has sometimes been called, is the work of Al Boll, who provided the brains and practical know-how for its installation, and Curt Boll, who provided the inspiration.

He also provided a site for it — in the middle of his 200-acre, wooded Newton County farm. Bertha is housed in a two-story building, which is divided by a partition into a control room, where the gas compressor is also located, and digester room.

The partition isolates the flame of the gas-fired water heater, and the sparks of electrical devices, from any gas leaks from the digester. The gas is both flammable and explosive.

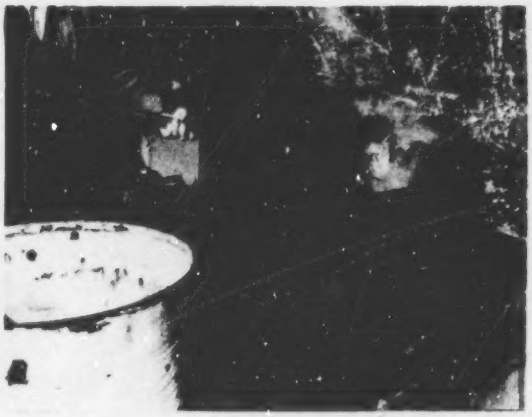
The Bolls say that if they were designing this plant again, they would provide even better isolation — and erect two buildings. The single building is well-insulated and measures 24 × 24 feet.

RAW MATERIAL

Different materials have been used to feed the Boll digester, including chicken manure, garden wastes, rotted alfalfa hay, walnut hulls, and hog entrails.

CONVERSION PROCESS

Boll begins with an open wood fire, on which the raw materials are cooked — outside the building — to extract juices and break down larger pieces.



An open wood fire is used to prepare raw materials for the slurry.

When the material is moved inside the building, it is made into a slurry, by adding water. Then the mixture is agitated in the mixing drum until it resembles baby food.

A valve is opened, transferring material to the sewer lift station. At the lift station, the slurry is further refined and then pumped into one of the digester tanks.

The anerobic methane-producing bacteria will thrive when the slurry has a carbon to nitrogen ratio of 30 to 1, a pH in the range of 7 to 8.5, and the temperature is 80 to 95 degrees.

After 20 to 30 days of initial digester charging, gas production will become evident from the pressure-gauge reading. With two tanks,

one of the tanks can be producing gas at all times, while the other is being filled.

At this point, the biogas is 45 to 60 percent methane, and the remainder is carbon dioxide, with less than 1 percent hydrogen sulfide.

The biogas processing steps begin after the gas leaves the digester by way of the gas release valve and gas lines, which direct it to the gas scrubber and condensation trap.

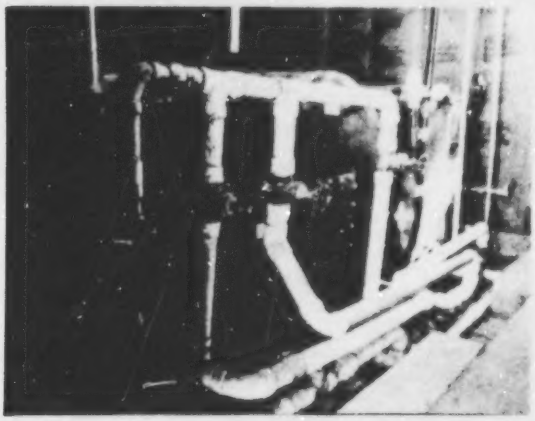
The condensation trap prevents moisture from getting into the gas compressor and the scrubber removes carbon dioxide.

On the gas line, as it emerges from the digester room, there is a reverse-acting siphon breaker valve — an emergency device that protects the installation, should gas expansion or contraction, due to temperature changes, cause a breakdown somewhere in the system.

Although plastic (floating) gas-bag collectors can be used to store gas in a low-pressure, huge-volume fashion, here the gas is compressed for storage in an outside storage tank.

The digester tanks are 1,000-gallon septic tanks whose seams were rewelded to withstand greater pressure. The tanks are 4 × 10 feet, made of steel. There is a bolted hatch, which provides tank access for cleanout and scum removal.

Curt Boll checks monitoring equipment on the digester tanks.



A bolted hatch on each of the 1,000-gallon digester tanks provides access for cleaning.

Three valves regulate the flow of the slurry into the appropriate digester. A vertical, clear plastic tube provides a visual check on the slurry level in the digester tank.

A thermometer and pressure gauge monitor digester conditions, while pH samples can be taken of slurry removed from a test valve.

Heat for the digester is supplied by the water heater in the adjacent room, circulated with a pump and transferred through a heat-exchanger coil located in the digester.

The condensation trap is a goose-neck design and the water is drained off by periodically opening a small spigot. The scrubber is a tank of lime water.

Plans have been made to install a hydrogen-sulfide removal process built around a filter of iron filings.

The compressor was pieced together, the heart of it coming from a condensing unit for a walk-in cooler. It is of cast-iron construction.

The compressor works automatically. Its pump motor operation is linked to control panel devices. There is a high-pressure, cut-out system, which prevents the compressor from starting if the gas pressure in the storage

tank equals the cut-out setting — typically 200 pounds per square inch.

If the digesters are producing gas, the low-pressure cut-in will start the compressor. Compressor operation will continue until storage is filled to maximum pressure, then the high-pressure cut-out will be activated.

If gas production continues, a safety valve on the digester will be triggered when digester pressure exceeds three pounds per square inch, and will vent gas to the atmosphere.

After the gas has been compressed into storage, the second-stage gas regulator reduces the pressure — before the gas reaches the house through a one-inch gas line.

Storage is a 400-gallon steel tank, which was purchased used for $75 at a local garage sale. It sits just outside the building.

Purchased at a local garage sale, this 400-gallon steel tank provides storage for the gas.

The methane gas is used for household cooking and sometimes for heating. A methane-powered electrical generator is sometimes used to power a portable air compressor, which operates an underwater aerating system in a catfish pond on the Boll farm.

Periodically, the rich, spent slurry and left-over sludge is removed from the digester by a large valve at the rear of the digester tank. This is a potent fertilizer, quite high in nitrogen.

Curt Boll once killed a small walnut tree, by pouring slurry full-strength on the tree. It should be diluted or drained into an aeration bed prior to use.

PERFORMANCE AND OPERATING HISTORY

The Boll biogas plant can produce about 275 cubic feet of biogas per day. One hundred cubic feet of gas will cook all meals for a family of four for one day.

The system originally demanded more attention, but now certain elements of the biogas plant operation have been put under automatic control.

Incidents have occurred that have necessitated design changes. Once the head blew off the Number 2 digester, which caused quite a mess and lots of cleanup work. That convinced them of the need for the digester relief valve.

The siphon breaker was installed after negative pressure, due to a sudden drop in temperature, caused one of the digesters to collapse.

COSTS AND BENEFITS

Slightly more than $5,000 has been invested in this facility, including $800 for the services of a carpenter. The Boll family labor is not calculated.

Methane gas and fertilizer have been the chief benefits. No records have been kept of actual production.

Alvin Boll published a book about the project, titled *Handbook of Methane Gas Production*, in partnership with Jack Fredricks. It was printed by Desert Publications.

Fire at Methane Digester at New Life Farm Puts Stop to Local Electric Production

New Life Farm
Drury, Missouri 65638
Telephone: 417-261-2553
or
Ted Landers
Perennial Energy
Box 15
Dora, Missouri 65637
Telephone: 417-261-2547
Government Grant: None

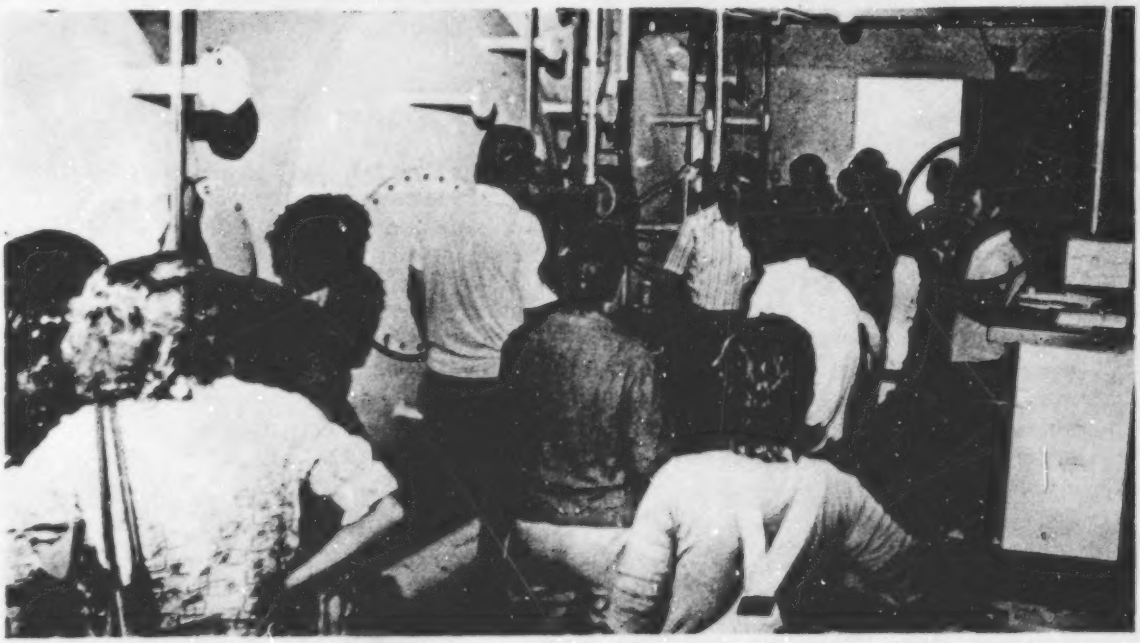
A Methane Digester That Uses Cellulose Was Built and Tested, But Burned Before Going Into Full Scale Production.

In 1975, Ted Landers received a research grant through the University of Missouri to build a digester that would digest cellulose — instead of the more conventional manure.

The 8,000-gallon, two-digester (reactor) tank system was installed at New Life Farm near Drury, Missouri. It was operational by 1979 and research began.

The cellulose digester successfully used hay, rotten hay, and cornstalks as feed. The research concluded that the carbon-to-nitrogen ratio (C/N) of rotten hay was too high to produce a good yield of biogas. After initial problems with pH control, the cornstalks produced a good quantity of gas.

As the biogas was produced, it was "scrubbed" and then stored for later use in huge bags. The storage bags were made of hypalon and fabri-



Ted Landers conducts a public tour of the digester facility at New Life Farm.

cated for the project by a waterbed manufacturer. Gas pressure in the bags was achieved by piling rocks on top.

According to digester technicians, "The single most significant problem with the cellulose digester was the inability of the stirring mechanism to homogenize the mixture in the reactor."

"The system consisted of an electric air compressor and air storage tank interconnected to run pneumatic cylinders, which pushed and pulled the stirring paddles back and forth," technicians said. "At best, this system used energy inefficiently and stirred the mixture poorly," the technicians concluded.

The major uses of the biogas produced were for generation of electricity and heating of the digester room. An induction motor used as a generator was employed for the former use. Plans were to employ a heat exchanger to recover waste heat from the generator engine exhaust. Up to approximately 9.2 kilowatts of power could be produced.

Negotiations were underway between New Life Farm and its local electric cooperative for sale of electricity to the utility as a model for mutually beneficial arrangement between farms capable of generating electricity with biogas and the local electric cooperative. The biogas produced at cooperating farms could be stored and held in reserve until the utility approached peak demand. Upon notification, these local biogas generators would be brought on line and make additional electricity available to the utility.

The advantage to the utility is that the price paid for electricity by the utility to its wholesaler is based on the dozen or so peak demands throughout the year. That same "peak price" is then charged all through the year, regardless of how much or how little is actually used. By "shaving" these peaks with supplemental locally produced electricity, the utility could significantly reduce the cost of purchased electricity.

Probably the biggest problem to overcome was gas storage. Generation time was limited to the size of the bag. In fact, later digester and biogas work by Perennial Energy discarded storage in favor of using the gas as it was produced. Induction generators were designed to run at varying speeds with varying electrical production depending on available gas.

The cause of the fire which destroyed the digester remains uncertain.

Unfortunately, these plans were never implemented. A clipping from **New Life Farm News** of March, 1981 explains why:

> On January 29, 1981, the cellulose digester of New Life Farm burned. The building and everything in it (except the steel reactor tanks) was destroyed. The heat was so intense that it melted the aluminum heads on the engine-generator into globs on the concrete floor.
>
> Since no one was at the facility when the fire broke out, and destruction was so complete, the cause of the fire will forever remain unknown. There are two probable causes that deserve mention. The first is a malfunction of the propane heater which had been working satisfactorily since it was relocated outside of the building last fall. The second is the spontaneous combustion of the approximately ten tons of chopped constalks stored in the building. One load of the stalks was delivered wet, which could have generated heat as decomposition of the wet material took place.

The fire was unfortunate in that the feasibility of the cooperative arrangement went untested.

Harrison Fire Chief Aids Fire Safety of Town by Lending Chimney-cleaning Equipment

Fire Chief Orville Main
Fire Station 1
Harrison, Arkansas 72601
Telephone: 741-6666
Government Grant: $400

Safety While Heating With Wood Is Promoted in Harrison by Fire Officials Teaching Chimney Sweeping.

BACKGROUND

No matter how much money the widespread usage of wood heat saves Arkansans, this satisfaction is lessened by the disastrous home-destroying flue fires that grab local headlines every winter.

Clearly, wood heat and wood heat safety must always be considered together.

In September 1980, Stephen Cook, director of the Energy Center of North Arkansas Community College at Harrison, approached local fire department officials with an innovative wood-heating safety idea. He suggested firefighters begin loaning chimney flue-cleaning equipment — free of charge — to the public.

He offered Energy Center funding and assistance to get the project going. Fire Department officials liked the idea and ever since, chimney flue-cleaning equipment, including brushes, extension handles, rope loop adaptors and instructions, has been available to the general public.

The equipment also has been made available to other communities, such as Jasper, and Capps/Batavia, on occasion. It is impossible to count all of the chimney flues cleaned by this equipment; several neighbors will use the equipment one person borrows. The college and the Harrison Fire Department recorded 500 loans by June 1983.

According to Orville Main, the Harrison Fire Chief, the program is very valuable. He said that he feels strongly that this fire-prevention program has "cut (area) flue fires down to practically nothing" and "saved a few homes".

The Harrison Fire Department recently put into its budget funds for replacing worn brushes; Energy Center funds for this are exhausted.

Main has been talking to other fire chiefs throughout Arkansas and there is considerable interest among them in starting similar prevention programs of their own.

Assistant Chief Fred Spry of the Harrison Fire Department demonstrates the proper way to clean a chimney flue.

6 Energy Center

Energy Center at Harrison Teaches Practical Applications of Alternate Energy Forms

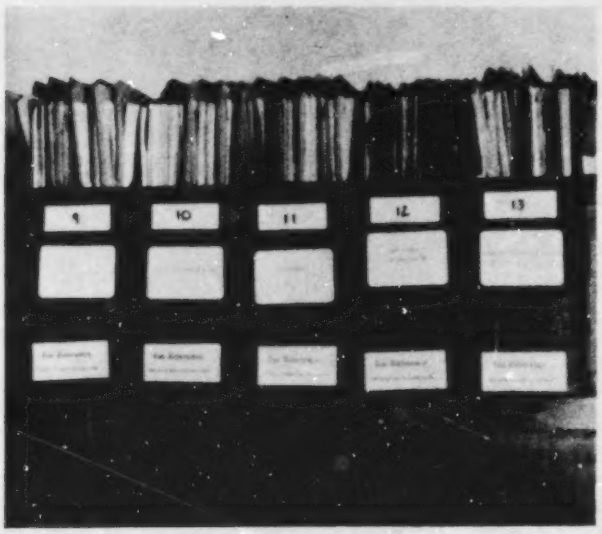
Merle Vincent, Librarian
North Arkansas Community College
Pioneer Ridge
Harrison, Arkansas 72601
Telephone: 743-3000
Government Grant: $40,000
This Energy Center Used Solar Energy and Provided Innovative Educational Experiences.

Unlike many two-year colleges that provided training for would-be solar professionals, North Arkansas Community College at Harrison pursued community-oriented solar energy education, from 1979 to 1983. Beginning with an evening general course entitled *Energy and Society* and a seminar, *Energy and the Way We Live* that was free to the public, in the 1979-1980 school year, the college eventually provided much more specialized solar energy education experiences.

In July, 1980 the college helped many Ozark residents who live in remote areas get electricity by coordinating a bulk purchase of photovoltaic panels. The purchase, pursued in conjunction with the college's order of photovoltaics for its own demonstration project, saw 36 families pool their resources and buy nearly $17,000 worth of solar cells at a savings of 36 percent off the single-unit price.

In August, 1980 the school received a nearly $40,000 United States Department of Energy grant to expand its solar energy course offerings, provide energy-related assistance to homeowners, operate an outreach program and set up an energy resource center in the campus library. The latter, which received electric power from the rooftop 660-watt photovoltaic array, provided these items:

Hundreds of energy-related books to borrow.
Elaborate, well-organized reference material, including building plans, product



The Energy Center at North Arkansas Community College has available to the public many publications, slide/cassette programs and other learning aids for the advancement of appropriate technology.

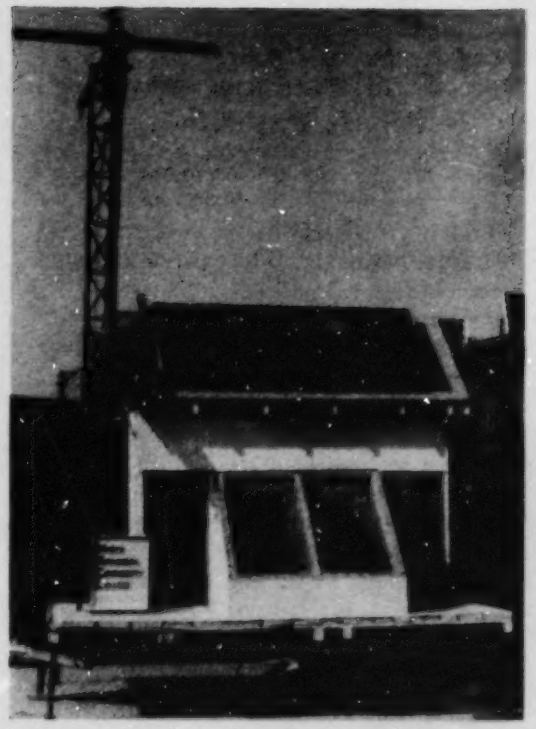
descriptions and catalogues, technical material, etc.

- Current and back issues of the leading solar periodicals.
- Slide/cassette-narrated solar programs —55 in all — available for immediate viewing on small-screen projectors; (many are "how-to-build-it" oriented).
- Equipment for loan (solar siting tools, wind-speed recording equipment, heat-loss detectors, chimney flue-cleaning equipment, etc.).
- A local solar energy services and products bulletin board.
- Loan slide programs/outreach presentations available to school or community groups.
- A library of 10 professional microcomputer analysis and design programs covering topics in passive and active solar energy and photovoltaic and wind power — for use with a Sinclair ZX81 16K microcomputer.
- Free publications on solar and energy conservation.

By late 1981, a mobile solar teaching lab called the "Solar Coaster" was completed. This 8 × 12-foot trailor-mounted unit, built with help from the Office of Human Concern's Solar Projects Crew, displayed three technologies:

1. A building of **passive** design, (including cooling features) with an attached solar greenhouse.
2. An **active** hot-water system with a 3 × 8-foot collector, part of a closed-loop system, which also included a 24-gallon tank with internal heat exchanger, differential thermostat, flowmeter, expansion tank, etc. and a 12-volt direct-current pump. This latter component was powered by . . . .
3. A **photovoltaic/wind electricity** system consisting of a 20-watt photovoltaic panel and a 200-watt wind generator on a 20-foot tower, which was lowered to 10 feet for travel.

Numerous monitoring gauges were used for instructional purposes. Unfortunately, transport stability problems limited the activities of this unit. It was used in conjunction with solar classes and workshops, however.



The "Solar Coaster" with its active and passive solar features serves as a teaching aid at NACC.

By May, 1983 nearly 300 people had taken one of the five mini-courses offered:

Physical Science:

104A *Solar and Energy-Saving Retrofits.*
104B *Passive Solar and Earth-Sheltered Home Design and Construction.*
104C *Active Solar Space and Water Heating.*
104D *Wind and Solar Electricity Systems.*
104E *Fuels from Farms.*

The cost of these mini-courses ranged from $7 to $10 per person. Typically, each course required four 3-hour week-night sessions, for which college credit was available if desired.

Between the fall of 1980 and mid-1983, nearly 700 people took advantage of free public lectures, many featuring outside guest speakers, conferences, and hands-on-workshops. Some of these activities are reported elsewhere

in this volume.

Energy fairs in the spring of 1980 and again in 1981 drew another 400 people.

Outreach activities conducted between fall, 1980 and spring, 1983 included:

- Eleven presentations given in seven outlying communities to over 400 people.
- Thirteen presentations given to roughly 260 students at surrounding area schools and colleges.
- Sponsorship of three open houses, held at area homes featuring innovative solar or wind projects; 425 people attended.

Finally, individualized assistance was provided to area residents in over 325 inquiries. Many letters from two-year and four-year colleges across the nation interested in solar-energy education were answered.

The North Arkansas Community Library in August of 1983 integrated the Energy Center resources, which were once separate, into the rest of the library. It remains an excellent place to go for help on solar energy projects. All of the resources are still available, with the exception of outreach presentations.

Many of the projects covered in this volume are documented in slide programs available at the library. A 12-page Energy Center catalogue is available, which lists nearly all of the resources available there.

FOLLOWUP INFORMATION

Stephen Cook, former NACC Solar Instructor, who directed the Energy Center and photovoltaic projects may be reached by writing or calling:

Stephen Cook
CompuSolar
Gum Springs Road
Jasper, Arkansas 72641
Telephone: 446-2211

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Many of these also may be found in the library of the Arkansas Energy Office at Little Rock.

Ask for them at your local public library; if they are not in hand, the librarian may agree to order them.

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